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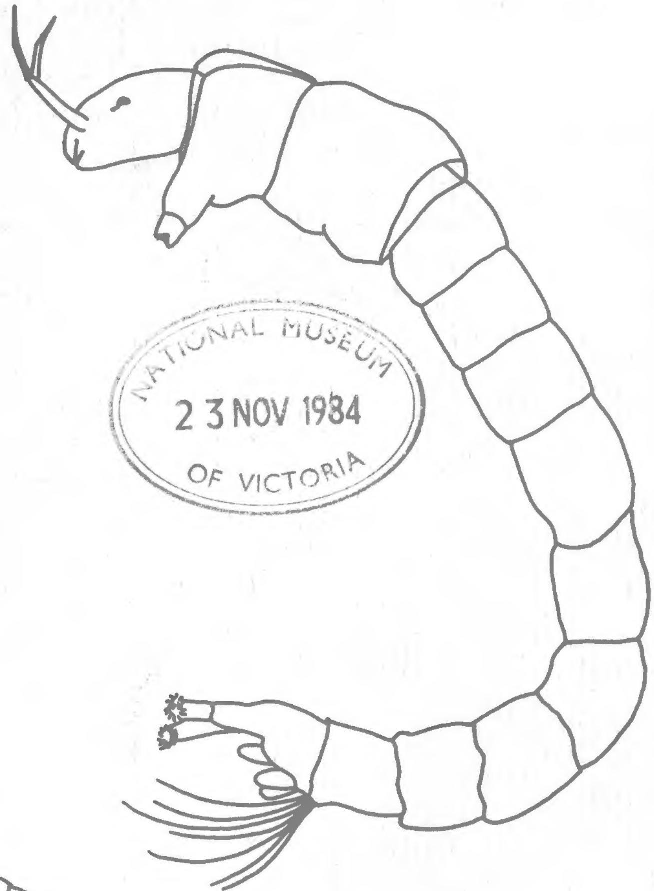

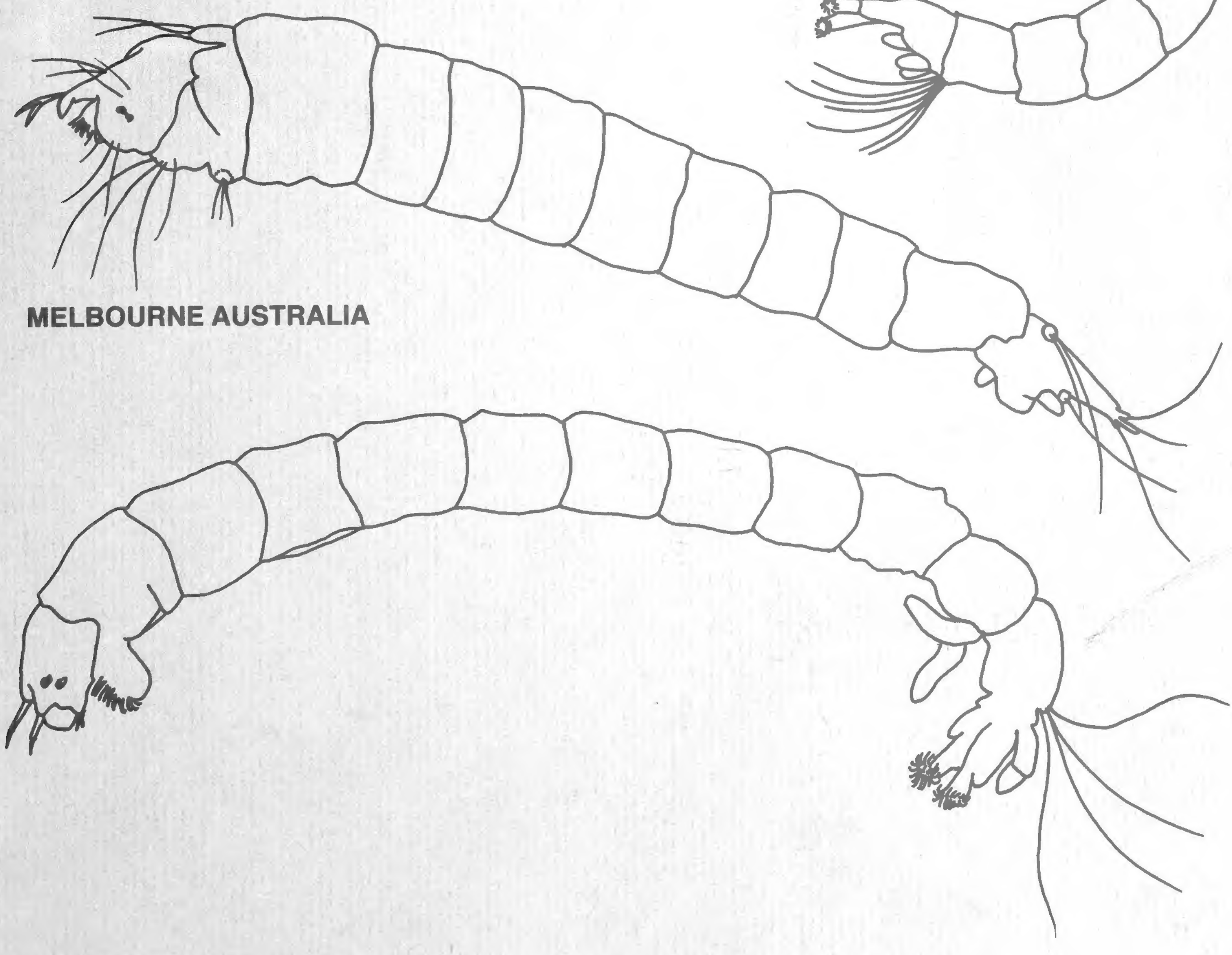

MELBOURNE AUSTRALIA

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Director Robert Edwards

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Occasional Papers from the Museum of Victoria

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The *Occasional Papers* are research documents of sufficient importance to be preserved but which are not appropriate for primary scientific publication. Papers are factual rather than interpretative studies, may be of special local interest or may be longer than a normal scientific paper. Contributions will be refereed if appropriate.

Two copies of the manuscript with accompanying plates and figures should be submitted to the Editor, Museum of Victoria, Russell Street, Melbourne, Victoria. Authors should consult a recent volume of the *Occasional Papers* to aquaint themselves with format.

Manuscripts must be typed on A4 paper, double-spaced, on one side of the paper and with ample margins. Captions to text figures and plates must be attached to the manuscript as final pages. Underlining in the text should be restricted to generic and specific names. Measurements must be in the metric system (SI units).

References should be listed alphabetically at the end of the manuscript. Abbreviations must conform with those in *A World List of Scientific Periodicals (1963–4, 4th edition)*, Butterworth: London. References to books must give the year of publication, edition, name of publisher and city of publication. Titles of books and abbreviated names of periodicals should be underlined.

Photographs must have clear definition and may be submitted as either glossy or flat prints at the actual size for reproduction. Line drawings for text figures should be in black ink on white card or drawing film. Maximum full-page size is 177 mm wide by 220 mm, single column width is 86 mm. Clear lettering must be inserted. Original drawings up to twice final size are acceptable.

Cover: Larvae of three species of midges of the family Chironomidae from Victorian freshwaters (from original drawings by Elizabeth Danne).

Occasional Papers from the Museum of Victoria 1:1-62 (1984) ISSN 0814-1819

The distribution of aquatic macroinvertebrates in the upper catchment of the LaTrobe River, Victoria

L. Metzeling, A. Graesser, P. Suter and R. Marchant

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Abstract. Metzeling, L., Graesser, A., Suter, P., and Marchant, R. (1984).The distribution of aquatic macroinvertebrates in the upper catchment of the LaTrobe River, Victoria. *Occ. Pap. Mus. Vict.* 1:1-62.

Seventeen sites in the upper catchment of the LaTrobe River were quantitatively sampled on six occasions between May 1979 and November 1980. A total of 308 taxa was caught: Ephemeroptera (29 taxa), Coleoptera (48), Diptera (49 Chironomidae, 51 others), Odonata (5), Trichoptera (76) and Plecoptera (26). Five site groups were evident when Czekanowski's index of faunal similarity was applied to the data. The three lowland sites were distinct from the foothill and headwater sites. In the last two regions, the five sandy sites were clearly distinguished from the nine cobble or mixed (cobble and sand present) sites; these last sites were further divided into six from the northern catchment, two from the southern catchment and the highest and coldest site (in the northern catchment). An inverse classification of the common taxa (>0.5% of total abundance; 39 taxa) revealed three major and seven minor taxa groups; the largest group consisted of taxa abundant at all sites while the other two major groups contained taxa characteristic of the cobble or mixed sites. The sandy sites were clearly depauperate when compared with the cobble or mixed sites. As a whole, faunal richness was comparable with that recorded in similar studies. The distribution of the various feeding groups (among the taxa) indicated that shredders decreased markedly in abundance at the lowland sites, as commonly noted in previous studies.

Introduction

The catchment of the LaTrobe River in eastern Victoria can be separated into upper and lower sections. The upper catchment, from the headwaters to the beginning of the lowlands, is mostly forested, naturally and in plantations, with some areas of timber cutting and small pockets of agriculture. The present study was confined to the macroinvertebrate fauna of the upper catchment. In the lower catchment the river flows through agricultural land and urban and industrial areas and is subject to many human influences. The fauna in this section of river is described elsewhere (Marchant et al., 1984).

The State Electricity Commission of Victoria (SECV), as a major user of the water from the LaTrobe River, commissioned the Museum of Victoria to examine the macroinvertebrate fauna of the upper catchment of the LaTrobe River. The work was carried out from 1979 to 1980 and formed part of a broader ecological programme, the LaTrobe Valley Water Resources Biological Study (LVWRBS).

The ecology of the macroinvertebrate fauna of Australian rivers has been very neglected. However, recent work on the Thomson River (Malipatil and Blyth, 1982; Davey et al., 1982) and the Macalister River (Malipatil and Blyth, 1982) has produced valuble information about such fauna for eastern Victoria. Our study provides more data on the distribution of lotic macroinvertebrates in this region and analyses the association between the fauna and habitat for a relatively undisturbed catchment in temperate (southern) Australia.

In order to relate the fauna to its habitat the catchment was sampled extensively and sufficiently frequently to cover the seasons. Regular quantitative samples of the benthos were taken, as well as measurements of important physical and chemical factors such as velocity, sediment size, temperature, nutrients and ions. To interpret these data various types of numerical classifications were used (Clifford and Stephenson, 1975). In addition, we have used information on the diets of some members of the fauna to analyse distribution patterns further.

Study Area

The LaTrobe River, above its junction with the Thomson River, drains a catchment of approximately 4600 km^2 in the Central Gippsland region of Victoria (Fig. 1). The catchment is bounded on the north by the Great Dividing Range and the Baw Baw Plateau and to the south and west by the South Gippsland Highlands or, as they are usually known, the Strzelecki Ranges. The river rises east of Powelltown, at an altitude of 760 m and flows initially in a south-easterly direction for about 70 km, after which the river flows east into Lake Wellington. In its upper catchment, around Noojee, the LaTrobe River is joined by many smaller tributaries, notably the Ada, Loch and Toorongo Rivers. The major northern tributaries are the Tanjil and Tyers Rivers both of which drain the Baw Baw Plateau. The major southern tributaries are the Morwell River and Traralgon Creek, while the Moe River drains the western region of the catchment.

The substratum of the rivers in the catchment varies

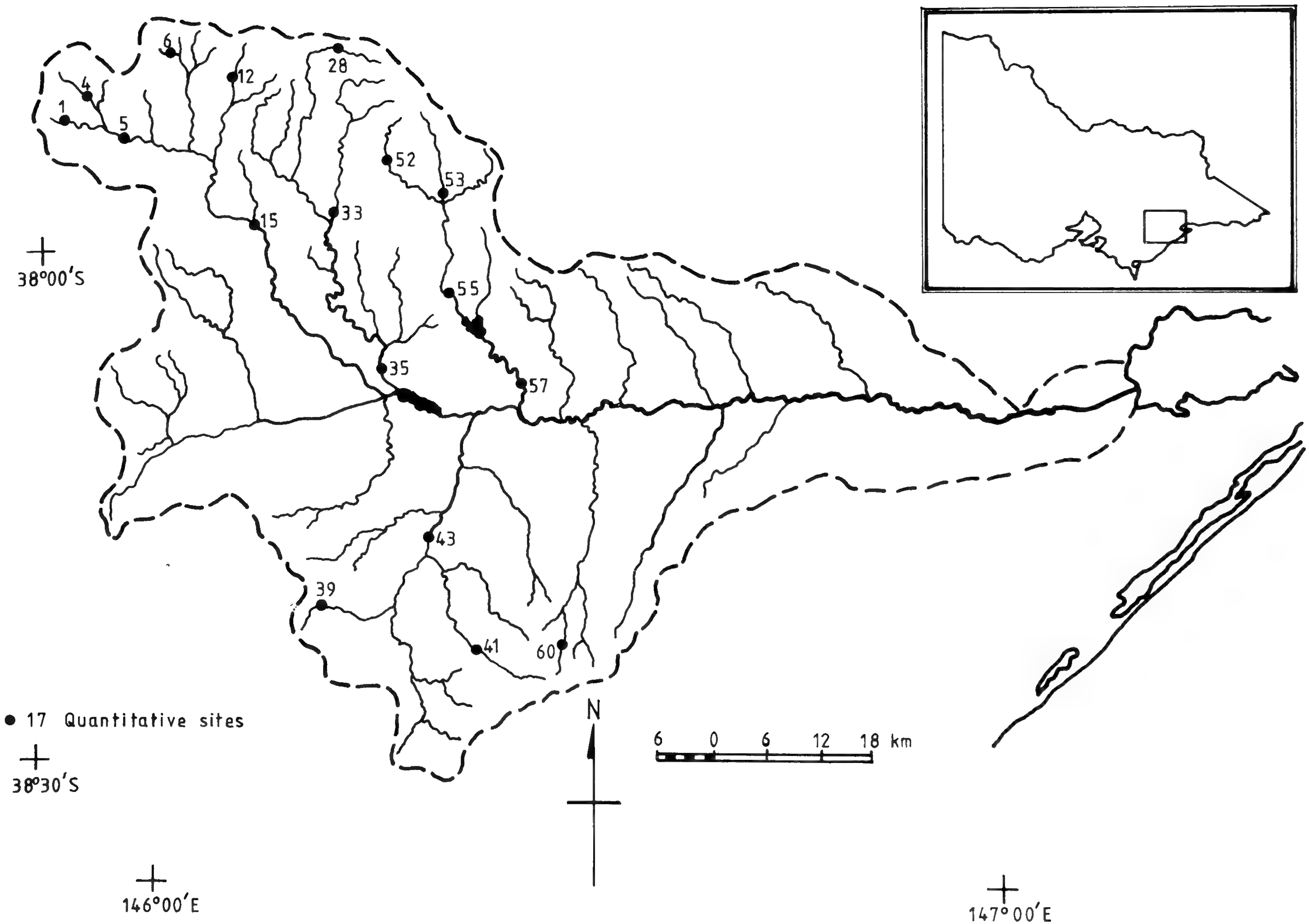


Fig. 1. Positions of the 17 quantitative sampling sites in the upper catchment of the LaTrobe River.

from sand to coarse gravel, cobbles and boulders. In the LaTrobe River sand predominates except in a short cobble section in the foothills. Coarse gravel and cobbles dominate the headwaters of the tributaries but the substratum tends towards sand and coarse gravel in the foothills and lowlands. The Morwell River, like the LaTrobe, is predominantly sandy along its length. Large boulders and bed rock are not major types of substrata, being found only in the headwaters of the Tyers, Tanjil and Morwell Rivers.

Rainfall
Annual rainfall varies from 1600 mm in parts of the northern catchment, to 800 mm in the lowlands of the LaTrobe Valley, and 1200 mm in parts of the Strzelecki Ranges (Bureau of Meteorology, 1976). Rainfall during the first year of sampling (1979) was lower than the long term yearly averages (Table 1), but was average during the second year (1980). Rainfall varies seasonally, with maxima during May-June and August-October, and minima in January-March. Stream flow varies accordingly, with maximum flows in the northern catchment being augmented in August-October by snow melt from the Baw Baw Plateau.

Site Descriptions
In a preliminary qualitative survey (Suter, 1979) 68 sites were examined but only 17 sites were chosen for quantitative sampling (Table 2); Fig. 1 shows their location within the catchment; Figs. 2-4 show the river profiles for the upper catchment of the LaTrobe River and its major tributaries. Three zones based on altitude and gradient were defined within the catchment. They were as follows:

Zone	Altitude (m)	Gradient (m km^{-1})
Headwater	›200	›5
Foothill	150-200	3-5
Lowland	0-150	‹3

Table 3 lists the general features of each of the 17 sites.

Although all the headwater sites in the northern part of the catchment are in forested land, not all are completely undisturbed as there are areas of timber felling in this region, notably near sites 4 to 12. Site 28 is the highest site and snow falls here regularly during winter. Its bankside vegetation is dominated by *Nothofagus cunninghami* (Hook) Oerst., unlike the other forested sites whose banks are dominated by *Eucalyptus* spp.

Site 35, on the lower Tanjil River, lies in cleared agricultural land. During 1979 the construction of the Blue Rock Dam was begun approximately 20 km upstream but the effects of this during the sampling were apparently negligible. Site 57, on the lower Tyers River, is downstream of the Moondarra Reservoir which reduced the flow at this site when compared with that at site 55 immediately upstream of the reservoir.

Site 39, on the Little Morwell River, while being in State Forest, is approximately 200 m below the outfall from a small sewage works. However, this produced no obvious effect. Site 41, on Middle Creek, has a very unstable rocky bed. During the study the substratum did not consolidate and the positions of riffles and pools were constantly changing between visits.

Sites 39, 41, 43 and 60 are located in the Strzelecki Ranges. While three of these sites (39, 41 and 60) are currently in forest the Strzelecki Ranges have been clear-felled twice in the past century (Forestry Commission, undated) and therefore all the forests present are regrowth. Such operations have probably altered stream morphology and increased the amount of sand and silt in the rivers of the southern catchment.

Table 1. Yearly rainfall (mm) recorded by the Bureau of Meterorology during the period of sampling.

Station	Long term yearly average	1979	1980
Noojee North	1414	907	1148
Tanjil Bren	1786	1688	2078
Moondarra Reservoir	1078	782	1058
Moe	965	694	866
Olsens Bridge (Strzelecki Ranges)	1383	1125	1420

Methods
Six surveys of benthic macroinvertebrates were undertaken at all 17 sites in May, August and November 1979, and February, May and November 1980. Ten samples were taken at each site; if both riffle and pool were present, five samples were taken from each habitat. At sites with a more uniform habitat, samples were taken from a range of velocities. At sites 28, 35 and 53, where distinct areas of both sand and cobble were present (mixed sites, Table 3), five samples were taken from both substrata. Samples were collected using a modified Surber sampler (Hellawell, 1978) (surface area 0.05 m^2) with two nets: a coarse inner net (1 cm mesh) trapped large particles of sediment and a fine outer net (150 micron mesh) trapped the finer sediments and the fauna. For each sample the substratum was disturbed to a depth of 10 cm by hand. Samples were preserved in 5% formalin and returned to the laboratory for sorting. There, a saturated solution of calcium chloride was used to float the light, mostly organic, fraction from the inorganic fraction. The inorganic fraction was searched for molluscs or caddis flies in cases and then discarded.

As the fauna in the organic fraction was generally mixed with a large amount of debris most samples were subsampled. A subsample was taken by placing the whole sample in a watertight box (36 x 36 cm) the bottom of which was divided into 100 compartments or cells. After the box was shaken animals and debris were removed from 10 cells (selected at random with random number tables) to give a subsample of one-tenth of the whole sample. This process was facilitated by the fact that the cells were removeable; the animals were trapped on mesh of 150 microns which covered the bottom of each cell. On a number of occasions we showed by counting the number of animals in each of the ten selected cells that the fauna was randomly distributed within the subsampler. This was confirmed in an experiment using rubber microvial stoppers (7 x 3 mm) to represent the invertebrates. In 15 sets of subsamples (each set consisting of five groups of ten cells) covering a tenfold range of densities the rubber stoppers were always randomly distributed.

The animals were picked from the subsample, identified under low magnification and preserved in 70% ethanol. All specimens were deposited in the Museum of Victoria. Animals were identified to species using published material or reference material from this institution.

Table 2. The quantitative sampling sites in the upper catchment of the LaTrobe River. Grid references were obtained from the National Topographic Map Series 1: 100,000.

Site	Locality	Grid Reference
1	LaTrobe R. at Powelltown-Noojee Rd	8022-950077
4	Ada R. at Ada R. Rd	8022-005106
5	LaTrobe R., 9.8 km W of Noojee	8022-016066
6	Loch R., 14.5 km N of Noojee at Loch River Rd	8022-093166
12	Toorongo R. 1 km S. of Toorongo Rd	8122-178174
15	LaTrobe R. at Hawthorn Bridge	8122-196968
28	Western Tanjil R. at Saxtons Rd	8122-294161
33	Eastern Tanjil R. at Tanjil Junction	8122-292963
35	Tanjil R. at Moe-Walhalla Rd	8121-357783
39	Little Morwell R. at Thorpdale-Mirboo North Rd	8121-286525
41	Middle Creek at Middle Creek Rd	8121-465487
43	Morwell R. at Driffield-Yinnar Rd	8121-415595
52	Western Tyers R. at Christmas Creek Rd	8122-343042
53	Middle Tyers R. above Tyers Junction	8122-414985
55	Tyers R. at Moe-Walhalla Rd	8121-412899
57	Tyers R. at Yallourn North-Tyers Rd	8121-516774
60	Traralgon Creek at Traralgon Creek Rd, 4.3 km from Grand Ridge Rd	8221-576475

Table. 3. Descriptions of the quantitative sampling sites in the upper catchment of the LaTrobe River.

Sites	Locality	Zone	Altitude (m)	Stream order	Substrata	Width (m)	Bankside vegetation
1	LaTrobe R.	Headwaters	360	2	Sand and logs	2.5	Wet sclerophyll forest with some *Nothofagus*
4	Ada R.	Headwaters	480	3	Sand and logs	3.5	Wet sclerophyll forest with some *Nothofagus*
5	LaTrobe R.	Headwaters	270	4	Sand and logs	8.0	Wet sclerophyll forest with some *Nothofagus*
6	Loch R.	Headwaters	400	3	Coarse gravel-small cobbles	2.5	Wet sclerophyll forest with some *Nothofagus*
12	Toorongo R.	Headwaters	740	4	Coarse gravel-small cobbles	3.0	Wet sclerophyll forest with some *Nothofagus*
15	LaTrobe R.	Foothills	153	5	Coarse gravel-small cobbles	18.0	Wet schlerophyll forest and *Rubus*
28	W. Tanjil R.	Headwaters	930	3	Sand and coarse gravel	6.0	*Nothofagus* rainforest
33	E. Tanjil R.	Foothills	180	5	Coarse gravel-cobbles	10.0	Wet sclerophyll forest
35	Tanjil R.	Lowlands	55	5	Sand and coarse gravel	15.0	Cleared agricultural land
39	L. Morwell R.	Foothills	170	4	Sand and logs	3.5	Wet sclerophyll forest
41	Middle Ck	Foothills	160	4	Coarse gravel-small cobbles	5.0	*Salix, Rubus* and cleared land
43	Morwell R.	Lowlands	58	5	Sand and logs	6.0	*Rubus* and cleared agricultural land
52	W. Tyers R.	Headwaters	360	3	Coarse gravel-cobbles	1.0	Wet sclerophyll forest with some *Nothofagus*
53	M. Tyers R.	Headwaters	240	2	Sand and small cobbles	2.5	Wet sclerophyll forest with some *Nothofagus*
55	Tyers R.	Foothills	190	4	Sand and logs	12.0	Wet sclerophyll forest
57	Tyers R.	Lowlands	59	4	Gravel-small cobbles	2.5	*Salix* and cleared agricultural land
60	Traralgon Ck	Headwaters	240	4	Coarse gravel-small cobbles	2.5	Wet sclerophyll forest with some *Nothofagus*

Where such information was not avaialble the animals were identified using a voucher system developed by the Biological Survey Department of the Museum of Victoria.

Additional faunal samples were taken by brushing logs (and occasionally rocks) with a firm paint brush in front of the mouth of a dip net (mesh size of 150 microns). The area brushed was approximately 0.1 m^2; samples were generally taken in moderate to fast flow and treated in the laboratory as above.

A preliminary survey in November-December 1978 qualitatively sampled 68 sites, taking up to four types of samples at each site: kick, log brush, sweep and leaf pack samples. All sample were collected using a triangular dip-net, with a mesh size of 150 microns.

Water temperature was measured at each site using a mercury thermometer. In addition, maximum and minimum thermometers encased in PVC tubing were placed in the river at nine sites throughout the catchment. Maximum and minimum water temperatures were recorded on subsequent trips.

Current velocity was measured at 0.2 and 0.8 of the depth above each of the ten sampling positions at a site using an Ott current meter. The average of the two measurements was taken as the mean velocity for each sampling position. At each site discharge was determined by measuring the depth and average velocity at regular intervals across the streams.

The mean particle size of the sediment at the cobble sites was measured in the field. The sediment collected in the coarse inner mesh of the Surber sampler was sieved while wet through a series of sieves with mesh sizes of -6, -5, -4, -3, -2 and -1 phi units, ie., 64 mm to 2 mm. The sediment collected in each size category was weighed on a

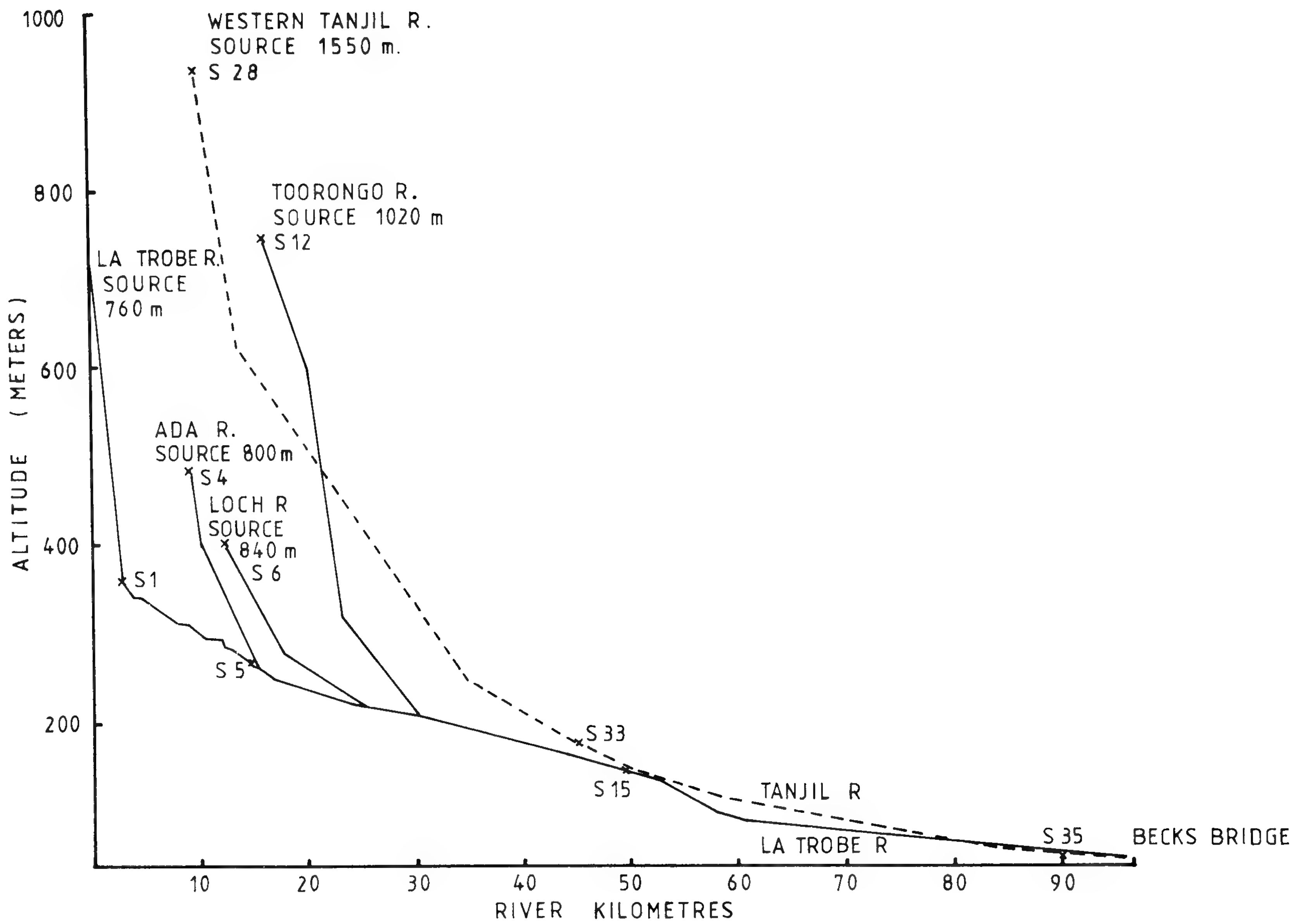


Fig. 2. River profiles for the LaTrobe and Tanjil Rivers showing the positions of the sampling sites.

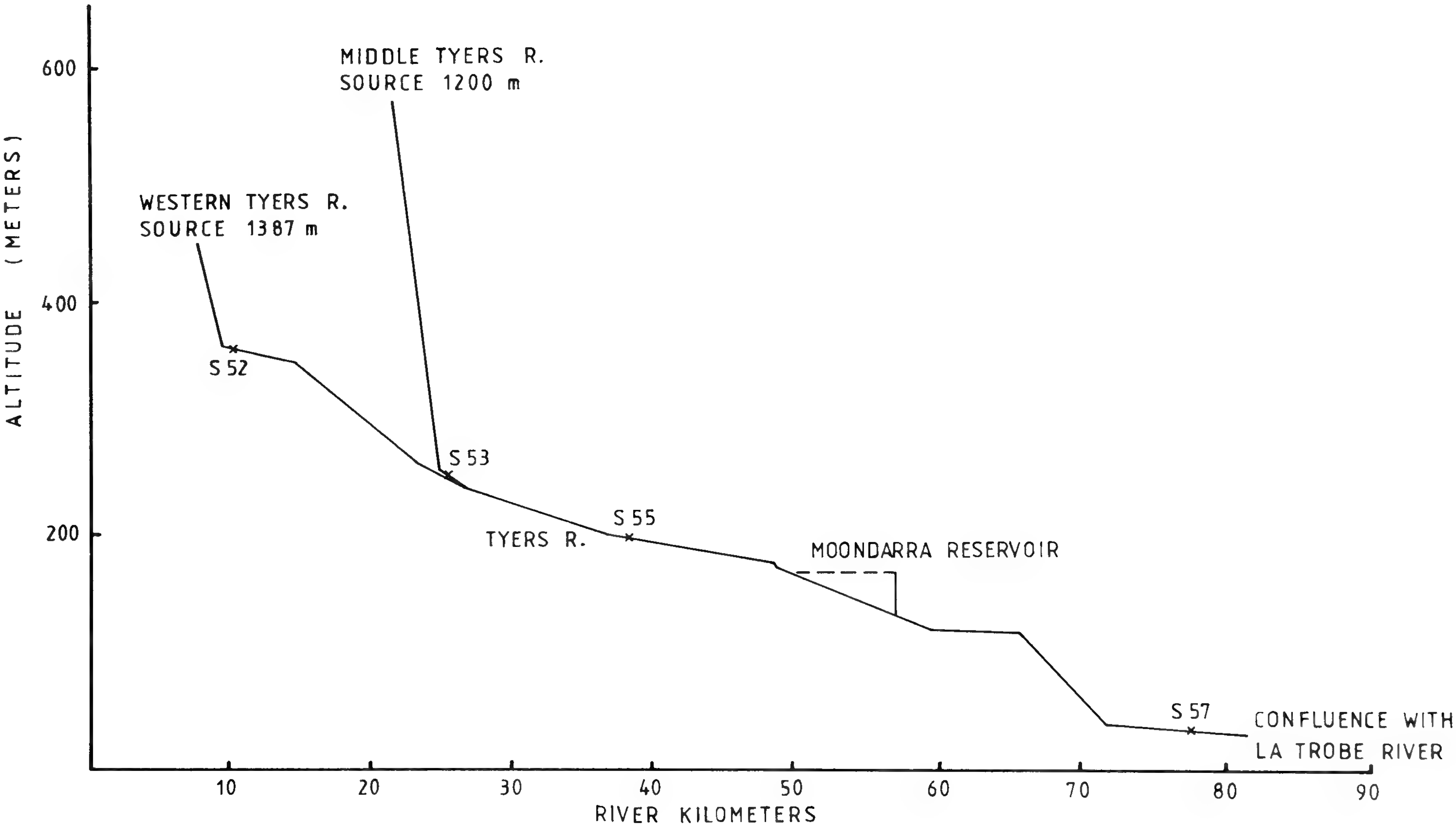


Fig. 3. River profile of the Tyers River showing the positions of the sampling sites.

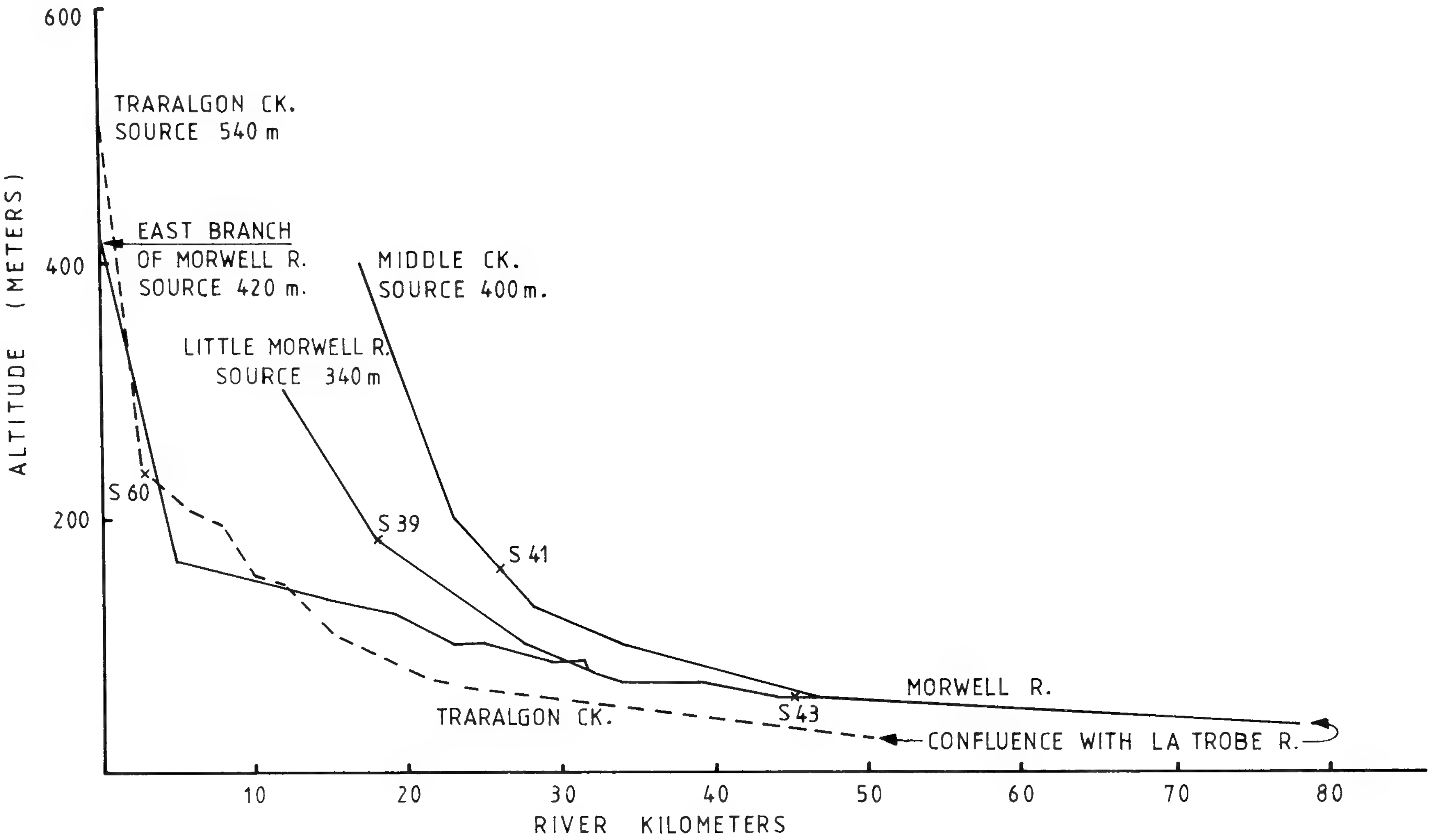


Fig. 4. River profiles of the Strzelecki rivers showing the positions of the sampling sites.

spring balance (6 kg maximum) to determine its percentage contribution.

The smaller particles of sediment (< 2 mm) were not easily sampled with the Surber sampler, and fine sediments were collected by inserting a 50 mm diameter plastic jar into the substratum adjacent to the sampling position. The mean particle size of such a core was determined by the Earth Sciences Department of Monash University using a series of sieves with fine meshes. At sandy sites (Table 3) only cores were taken, while at cobble sites sediments were sieved and cored.

The organic content of the material from the fine net (after floatation and subsampling for macroinvertebrates) was measured (by the SECV laboratories) by determining the weight loss of the samples after heating them to 600-650°C for 24 hours. The individual samples from a site were combined to form one composite sample, or, if both riffles and pools (or cobbles and sand) were sampled, two composite samples were formed, each combining five samples. This did not give absolute values of organic content, as organic particles <150 microns were not retained by the nets, but did provide an index for comparing samples within and between sites. The water quality of all sites was anlaysed on three occasions - November 1979, February and May 1980; the samples were taken from mid-stream at mid- depth. Chemical measurements were carried out by the SECV using standard methods (Anon., 1976) for various nutrients and ions.

Statistical and classificatory methods

The arithmetic mean number of individuals per sample and the 95% confidence limits (95% CL) were calculated for the ten samples at each site. Before calculating confidence limits all data were transformed to logarithms using $\log_{10}(x + 1)$ where x is the number of individuals. To convert the 95% CLs from the logarithmic scale to the arithmetic scale their antilogarithms were taken; the arithmetic means were then multiplied or divided by these antilogs to give arithmetic confidence limits. This combination of arithmetic means and confidence limits derived from logarithms was recommended by Elliott (1977) when dealing with small numbers of samples (<30) where the variance is greater than the mean, as occurred in our data.

To classify the sites on the basis of the composition of the taxa a number of similarity indices were used. Similarity based simply on presence or absence of taxa was measured with Sorensen's index (Hellawell, 1978):

$$S = 2c\,(a + b)^{-1}$$

where a and b are the number of taxa at two sites and c is the number of taxa found at both sites. To incorporate data on abundance of each taxon we used Czekanowski's index of similarity (Hellawell, 1978):

$$C = 2W\,(A + B)^{-1}$$

where A and B are the numbers of individuals at two sites and W is the sum of the lesser abundances of the taxa found at both sites. This index was calculated after transforming the abundances to $\log_{10}$ in order to lessen the influence of particularly abundant taxa. The Canberra Metric index (Clifford and Stephenson, 1975) was also used. This index was used only with untransformed counts.

Inverse classifications in which the taxa are compared on the basis of their distribution between sites were also done. Czekanowski's index with log-transformed data and the Canberra Metric index with untransformed data were used. Calculations were made only for taxa whose abundance was greater than 0.5% of the total population.

For both types of classification the sites or taxa were grouped using average similarity values, i.e., average linkage clustering, with programme BMDP1M (Dixon, 1981). The results were expressed as dendrograms.

Physical and Chemical Results

Temperature

As expected, the headwater sites were generally a few degrees cooler and experienced a smaller annual range of temperatures than either the foothill or lowland sites (Table 4). Also, a clear seasonal cycle was evident at all sites. Site 28, the highest site, consistently recorded the lowest temperatures of all sites (min. 2.3 °C) while site 57 on the lower Tyers River was usually the warmest (max. 21.4 °C).

Regression equations were calculated which related air temperatures recorded at local stations by the Bureau of Meteorology to water temperatures at nearby sampling sites. The annual water temperature cycles which were derived for four sites from these equations (Figs. 5a-d) confirm the trends of the spot readings of temperature.

Although nine maximum-minimum thermometers were place throughout the catchment, only four remained at the end of the study. The first readings are from August 1979 (Table 5). The most useful data, from three foothill and three headwater sites, confirm the seasonal trends

Table 4. Spot water temperatures (°C). The sites are grouped into headwater, foothill and lowland zones.

Site number	May 1979	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980
Headwaters						
1	8.5		10.2	11.3	9.7	14.5
4	6.9	5.3	7.9	10.2	8.8	14.0
5	8.0	6.9	11.0	12.4	9.0	16.0
6	8.1	5.7	9.2	12.2	9.4	-
12	5.9	4.1	7.8	10.1	7.4	14.0
28	5.6	2.3	5.7	8.0	5.8	12.5
52	6.8	4.5	8.5	11.4	8.6	13.0
53	8.6	6.2	9.7	10.8	9.2	17.2
60	8.5	7.7	12.4	14.4	8.7	14.8
Foothills						
15	9.2	6.8	10.7	14.2	10.5	16.8
33	9.0	6.5	13.5	11.8	9.2	13.6
39	10.8	8.7	13.2	16.9	11.5	18.7
41	9.0	7.5	13.4	17.8	9.6	18.9
55	9.0	6.5	12.0	17.1	8.7	16.8
Lowlands						
35	10.5	7.6	15.0	18.5	10.6	18.5
43	10.7	7.3	15.0	19.0	12.4	19.5
57	11.2	8.6	15.3	19.2	10.6	21.4

Table 5. Maximum and minimum temperatures (°C) at three foothill (33, 41, 55) and three headwater (4, 28, 52) sites.

Site	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980
4		5.5-10.5	8.2-15.5	7.9-15.5	
28	2.2-5.5	2.5-9.5	5.5-13.5	6.0-13.0	3.0-11.0
33	5.0-8.5	5.8-11.5	11.2-18.0	8.0-20.0	6.0-16.0
41	5.8-8.8	7.5-15.0	23.8-19.8	9.5-21.5	
52	3.4-7.2	4.5-10.5	7.5-19.5	9.0-17.0	4.0-13.5
55	4.5-9.5	7.0-13.5	9.0-22.0	9.5-21.0	6.5-18.0

outlined above and extend the range of temperatures, particularly the maximum temperature, experienced at these sites.

Velocity and Discharge

Since we selected at each site areas of rapid and slow flow for sampling, there were only small, but consistent, differences in velocities (Appendix 1) between sites. Velocities throughout the catchment ranged from 0.04 to 2.70 m s^{-1}; the majority were between 0.1 and 0.8 m s^{-1}; the majority were between 0.1 and 0.8 m s-1 Lower velocities were consistently recorded at sandy sites compared with rocky sites and in pools compared with riffles.

Stream discharge, a measured by our velocity and depth profiles (Appendix 2), showed consistent seasonal trends with maximum discharges in November and minimum discharges in February. The maximum discharge (8.9376 m^3 s^{-1}) was recorded at site 15 in August 1979 following several days of heavy rain. Traralgon Creek (site 60) consistently recorded the lowest discharge (0.0256- 0.1672 m^3 s^{-1}). Our values were similar to those obtained by the LaTrobe Valley Water and Sewerage Board (LVWSB), e.g., at site 15 our figures deviated by an average 27% from those of the LVWSB.

Particle Size of Substratum

The two types of substratum encountered during the study, cobble and sand (Table 3) were clearly distinguished by measurements of mean particle size (Table 6). It is evident that there was little variation in mean particle size at a site throughout the period of sampling, even at the sandy sites where the data were incomplete. Also, there was little variation between sites with a similar substratum, although two lowland sites (35 and 57) had smaller mean particle sizes than other sites for cobbles and sand.

The procedure for measuring mean particle size at cobble sites in the field underestimated the contribution of the smaller size classes (<4 mm); but, as indicated in Appendix 3, which shows the mean percentage contribution of each size class for each cobble site, there was a marked decrease in percentage weight with decreasing size class. Particles smaller than 4 mm probably contributed less than 1-2% of the total weight of a sample.

Core samples, taken alongside the surber samples at the cobble sites, had a mean particle size of approx. 1.4 mm (Table 7). While this figure was slightly larger than the mean particle size for the sandy sites (approx. 0.9 mm, Table 6), the means were not significantly different (t_{13} 1.73, $p > 0.05$). As indicated above, such size classes at the cobble sites contributed very little to the sediment and their exclusion from calculations of mean particle size would not have raised the estimates much.

Organic Content of Substratum

Estimates of organic content were made for each site for three sampling trips - August 1979 and May and November 1980 (Appendix 4). These values can only be considered as indices of organic content. The sampling procedure did not retain particles smaller than 150 microns and the samples were preserved in formalin; this preservative would have leached organic matter into the solution that was poured off before drying.

The organic matter consisted of leaves (though leaf packs were not specifically sampled), refractory material such as burnt twigs and other woody debris, and large organic particles. Generally, the highest levels of organic matter were recorded in May, which may indicate high summer and autumn leaf- fall. Many sites recorded an occasional high level of organic matter but site 39, which is downstream of a small sewage works, consistently recorded high levels.

Table 6. Mean particle size (mm) for each site on each visit. There are two entries for the three mixed sites (28, 35, 53).

Site:	1	4	5	6	12	15	28	28	33	35	35	39	41	43	52	53	53	55	57	60
Substratum	sand	sand	sand	cobble	cobble	cobble	cobble	sand	cobble	cobble	sand	sand	cobble	sand	cobble	cobble	sand	sand	cobble	cobble
May 1979	-	-	-	54.87	48.55	49.84	31.15	-	45.07	27.41	-	-	40.88	-	54.28	45.15	-	-	35.49	39.18
Aug 1979	-	-	-	51.29	49.69	55.73	46.46	-	51.76	25.46	-	0.95	44.39	0.72	53.41	42.22	-	0.74	35.69	42.41
Nov 1979	-	-	1.75	53.48	51.02	55.08	38.21	0.84	51.14	*	0.22	0.57	47.60	1.11	54.75	45.12	1.31	0.72	36.22	44.15
Feb 1980	-	0.91	1.86	52.69	51.40	54.43	40.42	0.93	45.18	21.08	0.55	-	46.06	0.70	52.63	38.42	1.38	-	38.22	45.17
May 1980	1.16	0.85	1.36	50.68	50.14	51.48	46.07	0.52	50.08	24.13	-	0.82	47.47	-	54.09	43.58	1.09	0.66	32.67	42.37
Nov 1980	1.57	1.09	1.63	53.16	48.45	54.72	43.43	0.56	55.90	26.58	0.51	0.57	48.90	-	53.64	45.21	0.93	1.10	32.51	39.68
mean particle size	1.37	0.95	1.65	52.70	49.88	53.55	40.96	0.71	49.86	24.93	0.43	0.73	45.88	0.84	53.80	43.28	1.18	0.81	35.13	42.18

* not sampled, - data lost

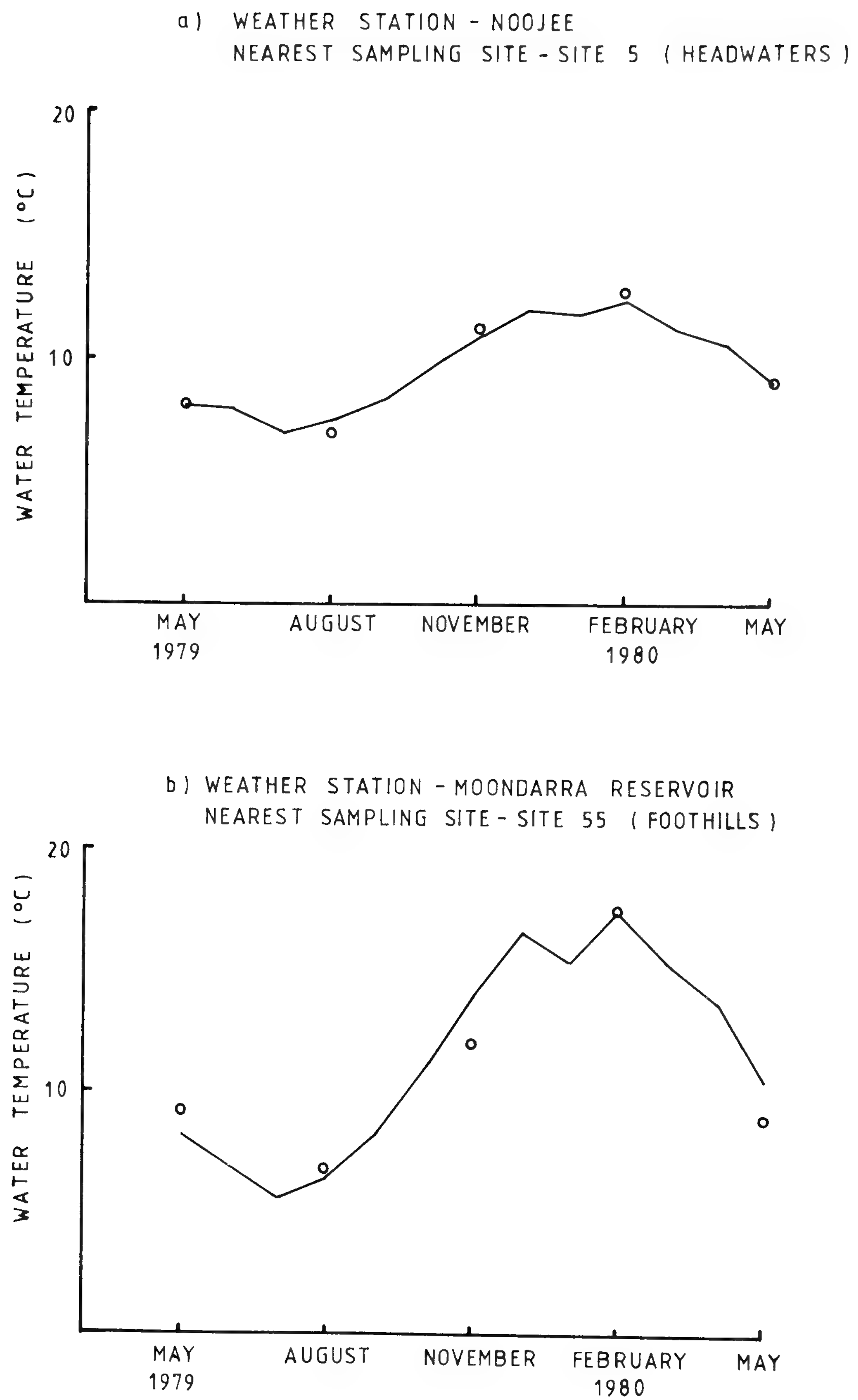
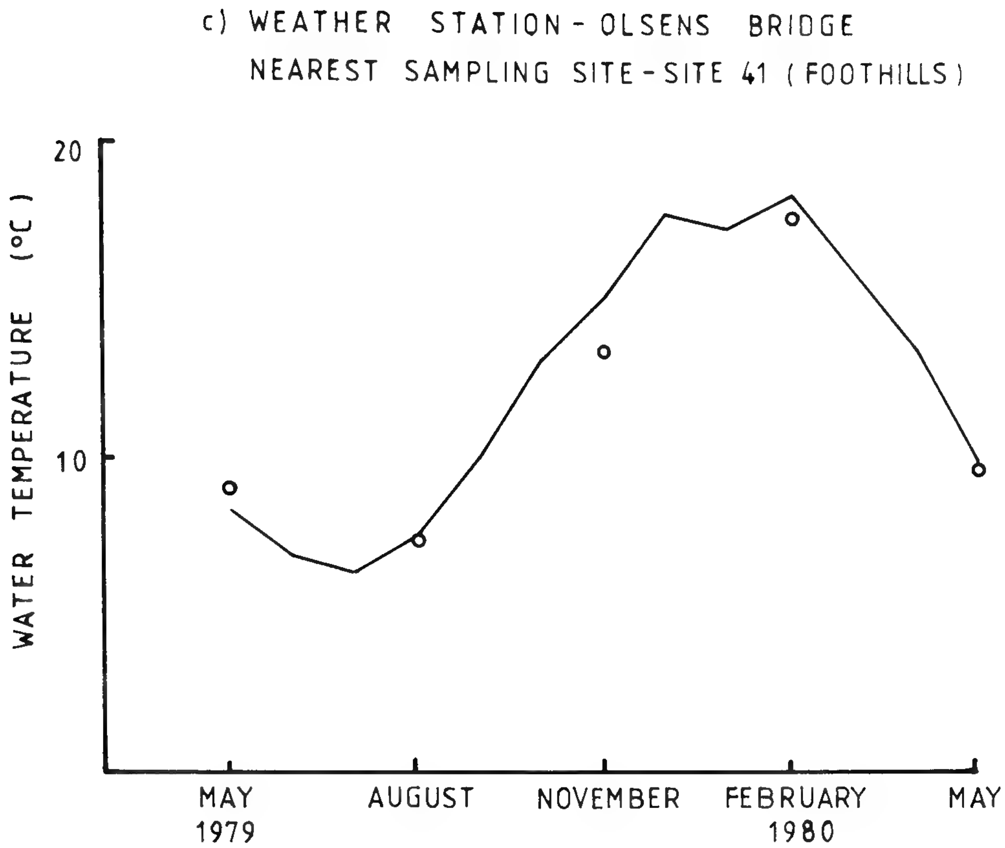


Fig. 5. Mean monthly water temperatures derived from regression equations for four sampling sites thorughout the catchment (unbroken line); water temperatures recorded while sampling are also shown (unshaded circle).



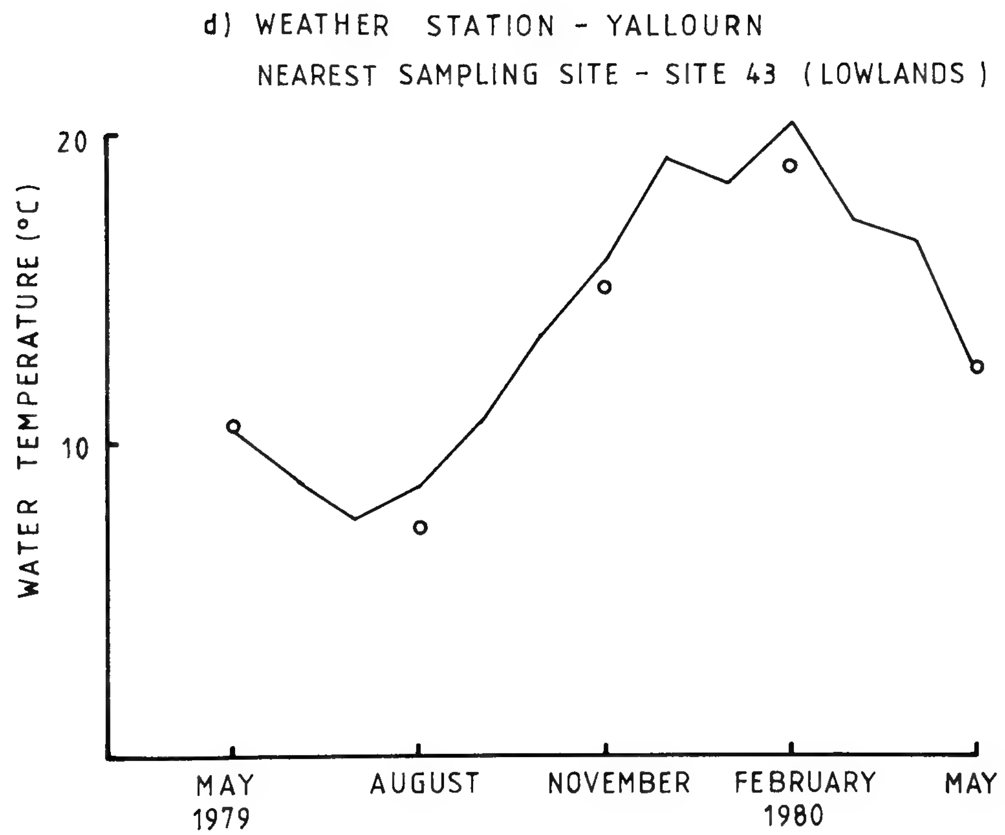


Fig. 5. (continued).

Table 7. Mean particle size of substratum (less than 4 mm) collected from alongside the sampling points at cobble sites. Dashes are missing data. There were no data for sites 12 and 57.

Site	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980	mean size
6	-	-	0.79	0.58	1.4	0.92
15	-	2.77	1.50	-	2.2	9.19
33	1.42	-	-	-	2.4	7.95
41	1.24	1.13	-	-	2.6	5.67
52	-	-	-	-	0.5	5.55
60	-	1.22	1.14	-	-	0.18

The levels of organic matter recorded in the pool and riffle sections of sites 41, 57 and 60 were compared using paired t-tests; no significant differences were found (t_2 0.91, 0.73 and 0.83, $p > 0.05$). On two visits (August 1979 and November 1980) more organic matter was recorded at sandy sites than cobble sites (t_{12} 4.28 and 4.02, $p < 0.01$); in May 1980, both sand and cobble sites contained similar levels of organic matter (t_{12} 0.34, $p > 0.05$). Two mixed sites (28 and 53) on the other hand, showed consistently higher levels of organic matter in the cobbles, but these differences were not significant (t_2 1.78, 1.34, $p > 0.05$). Thus, there were generally higher levels of organic matter in the sand than amongst the cobbles. Perhaps the usually lower water velocities at the sandy sites allowed more organic material to accumulate.

Water Chemistry

Measurements of the various chemical variables (Table 8) indicate that the northern and southern catchments differed consistently in a number of factors. The southern catchment recorded higher values for conductivity and TDS (3-4 times greater), bicarbonate and chloride (up to 6 times greater) and the cations sodium, calcium and magnesium (4-6 times greater). Conversely, the concentration of suspended solids was greatest, though highly variable, in the northern catchment and total organic carbon was highest at the Tanjil River sites. Concentrations of potassium varied irregularly throughout the catchment.

Concentrations of total nitrogen and total phosphate were highly variable, varying between samplings by up to one and two orders of magnitude respectively. Chessman (1981) recorded similar values and variations for these factors. Oxygen concentrations and biochemical oxygen demand were not measured, but Chessman (1981) reported that these streams are well aerated (range of 6-12 mgl^{-1} O_2) and possess low levels of BOD (<1 mgl^{-1}).

Faunal Results

General Features

A total of 308 taxa of benthic macroinvertebrates (excluding immature categories) (Appendix 5) were identified from the upper catchment of the LaTrobe River. The majority were insect larvae and nymphs, but crustaceans, molluscs and oligochaetes were also found. The number of taxa in the six major orders of stream insects were Ephemeroptera (29 taxa), Coleoptera (48), Diptera (100), Odonata (5), Trichoptera (76) and Plecoptera (26); half of the dipteran taxa were Chironomidae.

The taxa collected in the preliminary qualitative survey are listed in Appendix 6; also shown is the percentage frequency with which each taxon occurrred in the four types of samples taken. A more detailed analysis of these results can be found in Suter (1979).

The mean number of taxa per visit at each site and their 95% CLs are shown in Fig. 6. The cobble sites (except 57) clearly had more taxa than the sandy sites, as shown by the general lack of overlap of the 95% CLs. The numbers of taxa at two of the mixed sites (28 and 35) were similar to those at the richer sandy sites while the number at the third site (53) was little different from those at most of the cobble sites. It is notable that the mean number of taxa at the cobble sites was quite consistent: five of the eight sites had an average 61-66 taxa.

The total numbers of taxa found at each site during the study (Table 9) show more or less the same variation between sites as do the mean values given in Fig. 6. Also given in Table 9 are the number of taxa at each site on each visit. The highest number of taxa (85) was recorded from the Tooronga River (site 12) in August 1979 and the lowest number (21) from the LaTrobe River (site 5) in November 1979. It is evident from the values for total number of taxa per visit that there was some seasonal variation in the diversity of the fauna; the lowest number of taxa was recorded in summer (February) and the highest number in winter (August). The fact that the values for the total number of taxa per visit were very similar for the same months in different years suggests that the seasonal differences, although small, were indeed real.

To illustrate the comprehensiveness of our sampling the cumulative number of taxa in each of the ten samples at a site was calculated for all visits. Representative results are given for four sites (Fig. 7): three cobble sites with diverse faunas (sites 12, 15 and 41) and one sandy site with a depauperate fauna (site 1). At these four sites 73-85% of the taxa were recorded in the first five samples. Thus, by taking ten samples at each site, we were confident of collecting most of the taxa present.

Mean number of individuals per sample and 95% CLs are listed for each site on each visit in Table 10. The highest density (2531 individuals per sample) was recorded from Traralgon Creek (site 60) in November 1980; samples from the LaTrobe River above Noojee (site 5) had the lowest density (25 individuals per sample) in November 1979. Generally, greater densities were recorded in the colder months (May 1979, August 1979 and May 1980) than in the warmer months (November 1979, February 1980 and November 1980), as illustrated by the variations in mean density per visit. The seasonal changes in density for two cobble and three sandy sites are shown in Fig. 8. Samples from the Ada River (site 4) had relatively constant densities throughout the sampling period compared with the other sandy sites (5 and 43), which showed clearly higher densities in winter than in summer.

Table 8. Mean values or ranges for various chemical factors measured on up to three occasions (November 1979, February 1980 and May 1980). The sites are grouped into their geographical zones. pH values are from B. Chessman (pers. comm.). All readings are in mgl^{-1} except where indicated.

	Upper LaTrobe R.						Tanjil R.			Tyers R.				Strzelecki Ranges (southern catchment)			
Sites	1	4	5	6	12	15	28	33	35	52	53	55	57	39	43	41	60
pH	6.6	7.2	6.9	7.1	6.8	7.0	7.2	6.9	7.5	7.3	7.1	7.0	7.1	6.8	7.9	7.6	6.7
Conductivity ($mS\ m^{-1}$)	5.6	3.9	4.8	5.5	3.4	5.0	3.1	4.2	6.5	2.7	5.7	4.2	10.0	20.7	18.9	15.7	18.6
TDS	48.0	51.7	47.3	54.7	33.7	46.0	32.7	31.7	41.0	21.7	36.0	26.0	66.0	128.0	108.5	22.0	111.5
Suspended solids	30-173	19-105	24-225	26-236	15-80	42	7-82	9-20	26	6-23	14-121-	9-16	17	11-27	5-29	5-26	1-13
Total Organic Carbon	7.4	7.6	9.6	5.4	3.6	5.8	43.3	47.2	4.1	28.3	10.7-	8.6	3.0	8.0	7.1	0.3	5.8
Bicarbonate	12.3	8.5	9.3	13.3	9.3	10.4	7.5	12.5	10.0	7.4	8.1	8.6	13.0	21.9	39.5	36.0	36.5
Chloride	24.3	12.8	13.0	13.3	11.6	11.5	10.0	13.1	24.5	9.3	11.8	13.4	40.5	61.6	43.1	41.0	40.1
Total phosphate	.003-.430	.007-.170	.003-.230	.005-.390	.003-.230	.005	.004-.230	.004-.050	.004-.050	.004-.050	.004-.180-	.004-.050	.003-.050	.004-.100	.009-.011	.005-.120	.005-.150
Total nitrogen	.270-.830	.246-1.150	.190-.560	.198-.830	.212-.420	.660	.186-.520	.150-.410	.110-.280	.168-1.070	.208-.580-	.130-.720	.090-1.490	.180-1.340	.176-1.010	.190-.380	.128-.440
Sodium	6.6	4.7	6.3	6.1	3.2	7.0	2.6	4.9	7.4	2.8	3.4	4.7	16.1	26.3	23.5	19.0	18.7
Potassium	2.7	1.9	2.3	2.6	1.6	1.7	1.5	1.3	1.3	0.9	1.8	1.4	1.7	1.8	2.1	2.3	2.0
Calcium	1.0	0.6	0.8	1.3	0.7	0.9	0.6	1.0	1.0	0.5	1.1	0.9	3.5	3.9	6.8	8.9	5.3
Magnesium	0.9	0.7	0.8	1.0	0.7	1.1	0.4	1.0	1.4	0.7	1.2	0.9	3.2	5.9	6.6	5.8	5.0

Table 9. The number of taxa at each site on each visit

Site	May 1979	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980	total number
1	32	46	32	40	26	32	99
4	35	63	45	36	39	39	111
5	36	48	21	35	41	35	92
6	50	58	52	55	71	52	132
12	62	85	53	50	64	55	137
15	74	57	56	67	78	51	151
28	51	52	41	44	48	37	121
33	61	59	62	68	73	59	151
35	41	46	46	44	52	39	110
39	31	31	42	42	30	41	91
41	61	72	66	67	60	59	146
43	27	43	30	29	52	26	90
52	69	75	63	69	59	50	128
53	63	60	60	59	63	72	149
55	43	56	29	33	37	36	99
57	42	49	49	50	37	60	116
60	71	69	66	74	64	71	157
Total	178	197	182	168	172	180	

Table 10. Mean density (numbers 0.05 m^{-2}) and 95% CLs (in parentheses) during the study.

Site	May 1979	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980	mean density
1	130 (96-178)	103 (67-158)	79 (55-112)	269 (194-374)	60 (40-89)	119 (89-159)	127
4	197 (126-307)	284 (189-428)	278 (199-389)	268 (198-364)	247 (172-354)	233 (165-328)	251
5	297 (207-428)	73 (50- 106)	25 (13-47)	284 (210-385)	372 (193-716)	221 (134-363)	212
6	182 (127-260)	255 (191-339)	267 (202-353)	353 (246-505)	446 (322-618)	197 (142-272)	283
12	376 (293-483)	224 (163-308)	164 (115-234)	311 (255-378)	414 (301-569)	352 (290-426)	307
15	851 (664-1091)	523 (366-748)	477 (341-669)	860 (628-1177)	1326 (1052-1673)	302 (196-467)	724
28	367 (261-516)	307 (175-539)	149 (72-308)	134 (61-296)	232 (66-809)	115 (52-252)	217
33	746 (510-1093)	556 (370-836)	543 (442-666)	907 (751-1094)	758 (665-864)	485 (366-643)	666
35	752 (363-1559)	456 (202-1028)	207 (109-393)	254 (157-410)	718 (372-1386)	137 (50-369)	421
39	345 (211-561)	203 (133-310)	150 (114-196)	401 (295-546)	306 (217-431)	213 (145-315)	270
41	552 (299-1020)	1480 (1069-2050)	536 (402-716)	412 (299-568)	453 (293-702)	467 (278-785)	650
43	594 (365-966)	653 (323- 1316)	85 (17-420)	368 (162-835)	1134 (545-2358)	38 (24-61)	479
52	522 (390-699)	610 (458-813)	530 (385-731)	540 (382-764)	418 (359-487)	267 (203-350)	481
53	448 (282-760)	355 (243-519)	231 (153-347)	376 (220-643)	651 (465-911)	480 (203-1136)	424
55	465 (285-760)	323 (182-574)	119 (61-231)	100 (49-202)	140 (72-274)	98 (36-262)	208
57	343 (225-522)	1031 (629-1689)	283 (180-443)	1144 (806-1623)	945 (612-1460)	1127 (902-1409)	812
60	682 (370-1256)	1215 (639-2312)	939 (608-1452)	863 (537-1385)	1190 (939-1509)	2531 (1927-3325)	1237
Mean density per visit	461	509	298	461	577	434	

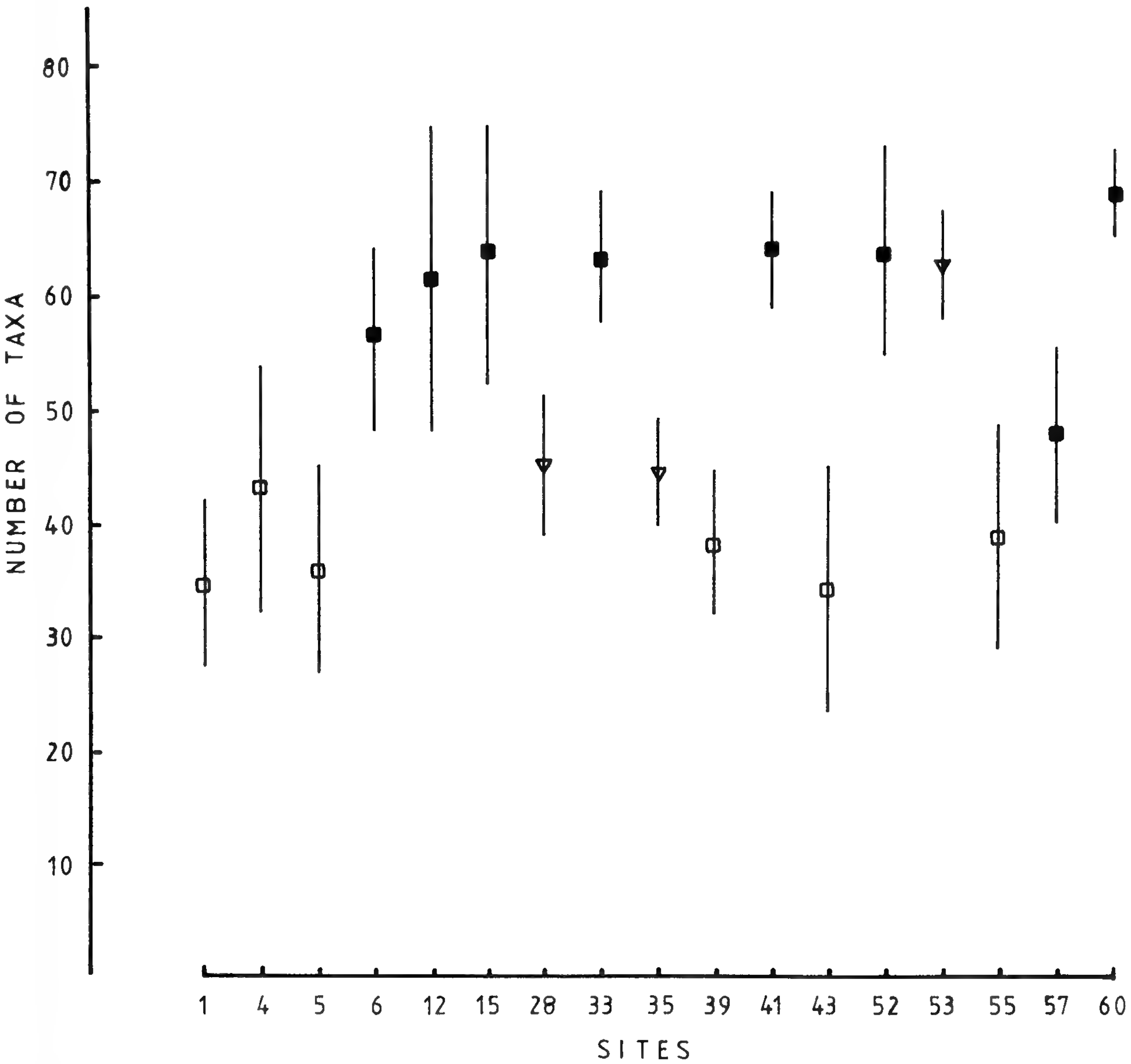


Fig. 6. Mean number of taxa per visit at each site. The bars show the 95% CLs. The type of substratum at each site is indicated thus: cobble, ■ ;sand, □ ;cobble and sand (a mixed site), ▽.

At the two cobble sites (sites 33 and 52) the seasonal fluctuations were not as distinct.

The values for mean density per site (from Table 10) indicate that densities were higher at cobble sites (307-1237) than at sandy sites (127 - 479); mixed sites were intermediate (217-424). Fig. 9 illustrates the variation in density between sites for samples taken in May 1980 when the highest number of specimens was caught. The same general pattern is evident and it is clear from the 95% CLs that in May 1980 density was less variable at the cobble sites than at the sandy or mixed sites.

To give a general idea of the variability of density at a site the 95% CLs were calculated as percentages of the mean densities. Results are given (Table 11) for six sites: two sandy sites (4 and 5), three cobble sites (15, 33 and 52) and one mixed site (28). Most confidence limits were equivalent to 30-40% of the mean densities. This degree of error was not so great that it obscured significant variations in density either between sites (Fig. 9) or between visits at a site (Fig. 8). The widest confidence limits were found at the mixed sites (28, 35 and 53) which reflects the differences in density between the fauna of the cobbles and sand at these sites. The narrowest confidence limits occurred at the cobble sites.

Subsampling contributed litte to the variability of the estimates of density. The trial described above (Methods), in which rubber stoppers were substituted for invertebrates in the subsampler, showed by analysis of variance that the variance of the 15 estimates of density was significantly greater than that due to subsampling ($F_{14,60}$ 13.14, $p < 0.001$). Thus subsampling added negligibly to the error in estimating mean density at a site.

The percentage abundance of the major groups of invertebrates during the study is given in Table 12. These values show that Chironomidae were usually the most frequently found invertebrates (about 30% of the individu-

Table 11. The 95% CLs expressed as a % of the mean densities.

Site	4	5	15	28	33	52
May 1979	46	37	25	35	39	30
Aug 1979	42	39	37	59	42	29
Nov 1979	34	67	34	79	21	33
Feb 1980	31	31	32	87	19	35
May 1980	37	70	23	160	13	15
Nov 1980	35	52	45	87	29	28

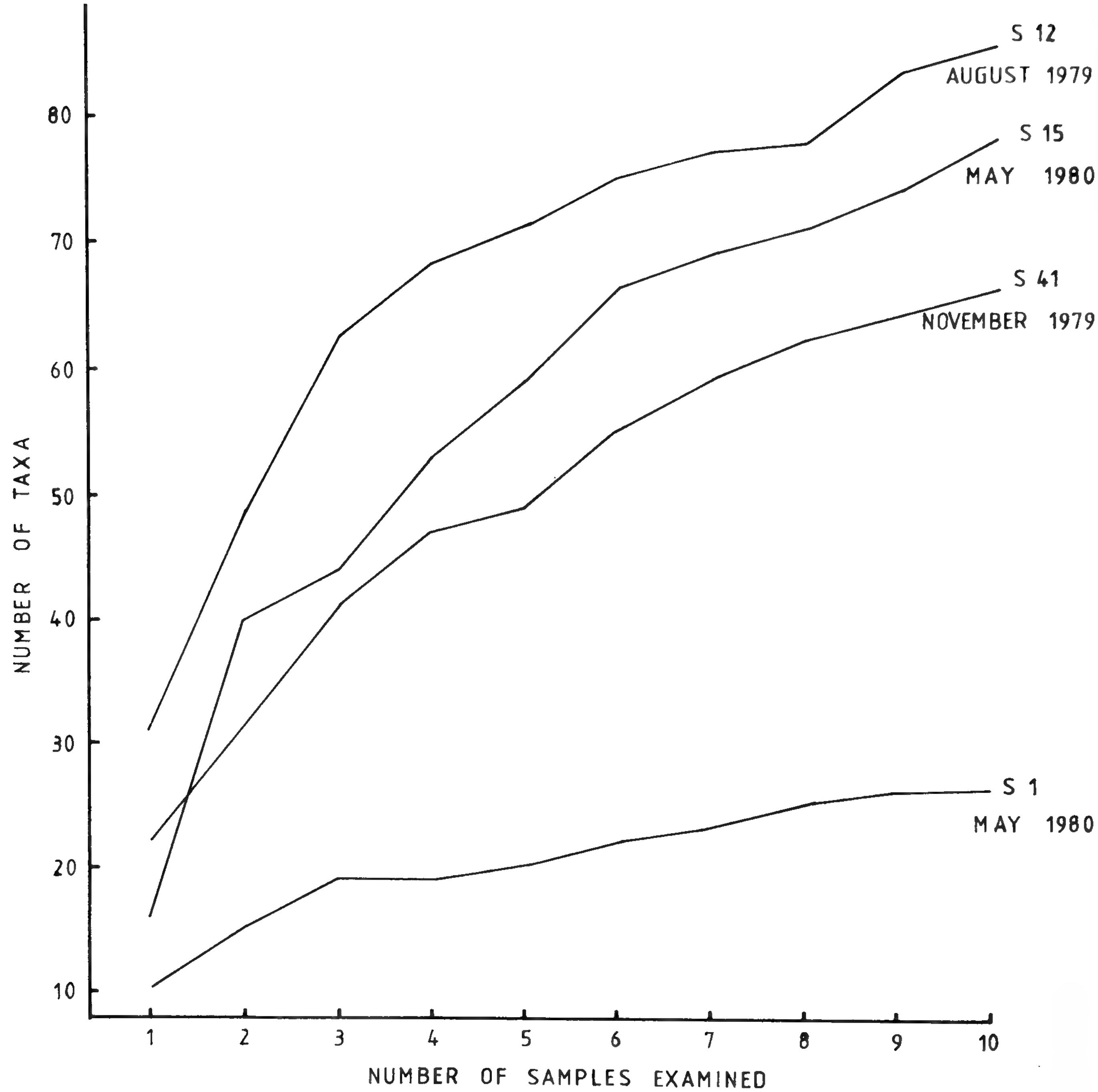


Fig. 7. Cumulative number of taxa versus the number of samples examined for selected sites.

Table 12. The percentage abundance of the eight major groups of invertebrates.

Site	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
Ephemeroptera	9	6	8	18	20	27	19	18	9	5	26	7	24	15	7	3	11
Diptera (excl. Chironomidae)	10	5	2	10	5	10	5	16	3	7	12	3	3	8	5	5	11
Chironomidae	24	26	37	10	16	32	30	22	28	39	29	68	30	29	49	34	47
Coleoptera	26	41	19	30	26	8	15	19	12	27	10	3	14	20	22	2	5
Trichoptera	2	1	1	9	11	11	5	6	3	1	7	2	17	7	4	19	13
Plecoptera	6	5	4	4	7	1	16	3	-	4	1	-	6	1	1	-	2
Oligochaeta	20	14	27	14	9	9	8	16	45	11	12	16	5	16	10	34	7
Others	3	3	3	4	5	2	1	1	-	12	4	1	1	3	2	3	6

Total number of individuals collected, site 1: 7569,site 4: 15062,site 5: 12717,site 6: 16994,site 12: 18397,site 15: 43402,site 28: 13035,site 33: 39946,site 35: 25237,site 39: 15147,site 41: 39014,site 43: 23483,site 52: 28873,site 53: 25415,site 55: 12455,site 57: 48729,site 60: 74198

als) at any site. Coleoptera, Ephemeroptera and Oligochaeta each represented about 15% of the individuals at a site; Trichoptera, Plecoptera, and non-chironomid Diptera generally constituted less than 10%.

One hundred and ninety-nine taxa (excluding unidentified groups) were collected in brush samples (Appendix 5). Of these only 17 taxa were restricted to logs (Appendix 7) and nearly all of these were rare, occurring at only one or two sites. Six of the 17 taxa were collected from site 28, a site with many submerged logs; and 14 of the 17 taxa were collected only from sandy or mixed sites. This last point emphasises the importance of logs as a habitat at sandy sites.

Classification of Sites

Sorensen's coefficient of similarity compares the faunal composition at different sites in terms of presence or absence of taxa irrespective of abundance. The dendrogram (a) in Fig. 10 is based on all taxa recorded at each site during the study; such data give the best general view of the faunal composition of the sites. Four groups of sites were formed.

The first group contained three sandy, headwater sites on or near the LaTrobe River (sites 1, 4 and 5). All three sites had low numbers of taxa (Fig. 6). Six headwater and foothill sites from the northern catchment of the LaTrobe River (sites 6, 12, 15, 33, 52 and 53) made up the second group. Each of the sites had a diverse fauna (Fig. 8); all were cobble sites except site 53 which was mixed. The third group consisted of three of the four sites from the Strzelecki Ranges (sites 39, 41 and 60). Two of these were cobble sites (41 and 60) with a rich fauna, while one (39) was sandy with a poor fauna. The fact that, despite these differences, the fauna was still sufficiently similar so that the sites formed a group suggests that the taxa restricted to the Strzelecki Ranges were having a major influence on the classification.

The three lowland sites (sites 35, 43 and 57) formed a group that was clearly separated from all others. These sites each had similar moderate numbers of taxa (Fig. 8) despite differences in substratum and location in the catchment. Two sites from the northern part of the catchment (28 and 55) were not closely associated with any others. Site 28 is the coldest headwater site (Table 4) and has a mixed substratum with a moderately rich fauna. Site 55 is a sandy foothill site with a poor fauna.

Czekanowski's coefficient of similarity compares the abundances as well as the composition of the fauna at the sites. The dendrogram (b) in Fig. 10 is based on the total number of individuals in each taxon collected during the study. The Canberra Metric index gave the same groups of sites and is not presented here.

The classifications based on Sorensen's and Czekanowski's coefficients were very similar. Only sites 55 and 39 shifted position; both are sandy sites and grouped with the other sandy sites (1, 4 and 5) when using Czekanowski's index. This close similarity between classifications implies that both were influenced by the same taxa. Thus the rare taxa, which have little influence on Czekanowski's index, were not only numerically rare, but must also have occurred only sporadically among the sites if they were not to influence Sorensen's index. This conclusion does not apply to sites 39 and 55 which must have a number of numerically rare taxa that influence Sorensen's index but not Czekanowski's index.

The distinction between the lowland sites (group E; 420-810 individuals per sample) and all other sites was preserved with Czekanowski's index. In addition, in the headwater and foothill zones all the sandy sites (group A; 120-250 individuals per sample) were clearly separated from the cobble and mixed sites. These last sites were themselves clearly split into the sites from the northern catchment (group B; 280-660 individuals per sample), the Strzelecki sites (group D; 650-1200 individuals per sample) and site 28 (group C; 220 individuals per sample), the highest site. This classification suggests that the sandy sites might be considered as depauperate (in terms of both numbers of individuals and taxa) versions of the cobble sites. Table 13 indicates how the sites varied during the study in their membership of the five site groups derived from Fig. 10b. On three of the six visits (May 1979, May 1980, November 1980) the classifications of the sites were generally similar to that in Fig. 10b. However, in May 1980 the sites in group A were clearly separated from all others and were not as closely related to groups B, C and D as were the sites in group E. In November 1979 and February 1980 most of the sites in groups A and E formed a single group that was distinct from the other groups while in August 1979 sites 1, 5 and 39 from group A were clearly separated from the other groups. On all visits the sites in groups B, C and D were associated with each other. The association between some of the sites in groups A and E (on three of the six visits) indicates similarity between the two most depauperate (in numbers of taxa) groups of sites.

Such variation in the grouping of sites suggests that interpretable biological classifications only emerge when more than one or two sets of samples are taken. This is the result, at least partly, of the seasonal variation in numbers of taxa (Table 9) and numbers of individuals (Table 10).

Table 13. The membership of the five site-groups (Fig 12B) on each visit based on Czekanowski's index ($\log_{10}$ data).

Site-groups: Sites:	A (1, 4, 5, 39, 55)	B (6, 12, 15, 33, 52, 53)	C (28)	D (41, 60)	E (35, 43, 57)
May 1979	1, 4, 5, 35, 39, 55	6, 12, 15, 33, 52, 53	28	41, 60	43, 57
August 1979	1, 5, 39*	15, 33, 52	4, 6, 12, 28, 53	41, 60	35, 43, 55, 57
November 1979	1, 5, 35, 39, 43, 55, 57	15, 33, 52, 53	4, 6, 12, 28	41, 60	
February 1980	1, 4, 5, 35, 39, 43, 55, 57	15, 33, 52, 53	6, 12, 28	41, 60	
May 1980	1, 4, 5, 39, 55	6, 12, 15, 33, 35, 52, 53	28	41, 60	43, 57
November 1980	1, 4, 5, 39, 55	6, 12, 15, 33, 52, 53	28	41, 57, 60	35, 43

*Sites 1 and 5 and site 39 were grouped separately, but are shown together here for convenience.

Table 14. The total numbers of individuals in each of the 39 common (>0.5%) taxa at each site. Horizontal lines divide the taxa-groups from Fig. 13 (1-10). The composition of site-groups is given in Fig. 10b (A-E).

Site-groups			A					B				C	D			E	
Stations	1	5	4	55	39	6	12	15	33	52	53	28	41	60	35	43	57
Species group **1**																	
Potomopyrgus niger	25	107	-	-	760	50	10	-	10	-	20	-	1055	2880	-	20	-
Species-group **2**																	
Atalophlebiodes sp. 1	35	81	-	50	-	1435	2070	3485	2184	2718	1897	636	50	738	431	50	163
Baetis sp. 3	60	20	-	-	5	18	146	1897	532	434	30	200	540	632	20	5	55
Austrosimulium furiosum	25	5	-	45	40	30	82	1390	1650	20	110	35	870	1580	40	80	210
Leptoceridae immature	10	15	-	20	5	30	11	2710	980	1160	90	15	215	1190	100	25	10
Austrosimulium victoriae	-	-	20	25	-	90	70	820	1091	60	170	10	740	2110	11	30	0
Simuliidae immature	40	-	-	5	-	205	100	1050	1950	90	355	-	830	2730	10	165	720
Species-group **3**																	
Atalonella sp. 2	95	235	43	40	96	182	191	75	41	70	40	30	845	101	379	220	215
Rheotanytarsus sp. 1	10	20	174	240	110	175	63	2005	940	170	340	195	3385	7390	530	105	3550
Cricotopus sp. 1	50	37	803	120	565	105	61	940	310	210	110	115	2415	6685	569	470	1902
?Eukiefferiella sp. 1	-	158	127	80	40	95	59	290	140	240	365	290	670	3175	360	220	1230
Polypedilum sp. 1	25	660	117	55	120	30	26	650	180	150	160	145	500	4225	49	4465	1625
Pentaneura sp. 1	30	342	124	105	475	85	145	215	130	220	205	170	285	1220	124	1090	171
Chironomidae immature	40	192	171	150	75	115	114	730	200	345	180	135	260	3915	229	265	880
Hydracarina unidentified	55	161	116	70	80	160	704	530	380	120	605	80	175	640	61	110	1075
Thienemanniella sp. 1	35	38	86	60	170	45	42	515	250	250	15	30	280	1355	781	100	220
Baetis immature	-	31	55	25	20	30	105	250	250	90	65	415	410	390	150	110	131
Cyphon sp. 1	997	535	187	300	110	395	545	60	320	201	543	275	160	410	70	10	10
Tipulidae sp. 1	364	218	296	249	597	111	50	120	134	91	294	167	134	201	91	141	75
Austrolimnius adults unident.	50	52	1073	490	115	580	954	505	1040	560	615	395	265	140	152	40	4
Riethia sp. 1	95	2163	267	860	60	115	186	4915	890	290	375	520	320	370	286	35	1475
Austrolimnius sp. L10E	235	423	3539	1695	2245	3045	1742	2390	5250	2490	2175	975	2230	1480	2076	420	375
Leptophlebiidae immature	130	433	357	170	595	364	1367	2270	1440	3270	1625	216	2365	3370	307	650	431
nr *Cordites* sp. 1	1086	743	1411	1770	1935	110	877	350	1330	2280	1890	825	420	20	2473	470	1227
Austrolimnius immature	5	130	540	125	385	340	390	305	730	-	550	30	20	60	565	50	0
Calopsectra sp. 1	290	207	247	200	1175	60	395	1170	120	170	705		1680	860	429	8155	1750
Species-group **4**																	
Austrolimnius sp L13F	40	407	100	15	-	70	245	-	390	400	305	20	375	20	-	-	90
nr *Eukiefferiella* sp. 1	-	-		10	-	370	214	110	300	545	100	210	135	360	-	40	150
Podonomopsis sp. 1	-	-	41	45	-	155	177	20	710	1055	165	605	130	210	1	5	0
Agapetus sp. 1	-	1	35	5	20	665	939	280	310	1737	390	115	270	160		10	5
Species group **5**																	
Tasmanocoenis sp. 2	45	-	20	285	25	-	45	2270	1860	50	30	5	1175	580	1	20	10
Stempellina nr *bausei* sp. 1	10		-	30	30	90	20	170	30	10	55	-	80	1650		-	10
Species group **6**																	
?Parachironomus sp. 3		31	7	895	170		-	80	150	50	115			10	446	25	678
Species group **7**																	
?Skusella sp. 1	-	60		25	-	10	30	730	180	1855	1835		-	710		-	-
Species group **8**																	
Atalophlebioides sp. 3	-	-		-	25	-	-	1230	30	15	10	-	3687	1755	129	250	83
Notalina bifaria	-	-		10	-	-	-	540	80	210	30	-	210	2334	61	-	
Species group **9**																	
Baetis sp. 1	200	42	331	10	-	538	-			140	-	772	125			-	0
Austrocercella mariannae	60	10	198		60	50	71		-	185	-	400	355	960		-	10
Species group **10**																	
Cheumatopsyche sp. 1				-	-			10	-	11	10	10	-	-	15	-	4768

Inverse Classification of the Fauna

All taxa that formed at least 0.5% of the individuals collected on a trip are listed in Appendix 8. In total, 63 common taxa were recorded. The inverse analysis was carried out only on the 39 taxa which each formed at least 0.5% of the total number of individuals from all samples. These included 20 taxa that always occurred at a frequency › 0.5% and 15 taxa that did so on at least half the visits. Oligochaeta were not included in the inverse analysis, although they always constituted › 0.5% of the fauna at a site. The 39 common taxa formed 62% to 75% of the fauna collected from all sites on a visit and with the Oligochaeta formed a constant 85% of the fauna.

Fig. 11 shows the inverse analysis using Czekanowski's index ($\log_{10}$ data); ten groups of associated taxa were evident. Table 14 shows the abudances of these taxa at each site. Fig. 12 summarises Table 14 by giving the mean densities of the fauna in each group of taxa for each site-group. The Canberra Metric index gave a very similar classification of the taxa and is not given here.

There were three major taxa-groups that comprised three or more taxa; the other seven groups comprised single taxa or pairs of taxa. Group 3 was the largest group with 19 taxa that were more or less equally abundant at the five site-groups (Fig. 12). Six taxa in this widespread group were not surprisingly unidentified or immature categories. Group 3 represents those taxa that were presumably tolerant of the varying physical and chemical conditions at the various site-groups.

The next largest groups (2 and 4) consisted of taxa that were most abundant in the cobble or mixed sites of the headwaters and foothills i.e., site-groups B, C and D. The simuliids (*A. furiosum, A. victoriae* and Simuliidae imm.) which require a firm substratum for attachment were notable in group 2. The taxa in groups 5 and 7 were also largely found at cobble or mixed sites but were not found at the highest site (28) nor in the lowlands suggesting they avoid high and low temperatures.

Group 1 consisted of a gastropod (*P. niger*) that was numerous only at Strzelecki sites. The sole taxon in group 10, a hydropsychid, was very abundant at the lowland site (57) downstream of a dam. Such a site would provide abundant zooplankton for filter feeding hydropsychids. The pair of taxa in group 9 avoided the lowlands; as one of the taxa was a plecopteran, (*A. mariannae*), it is probable that the pair was restricted to cool water. The final two groups (6 and 8) consisted of taxa that were common in the lowlands and extended to either sandy or cobble sites in the headwaters and foothills but avoided the highest (and coldest) site.

The mean densities of the Oligochaeta (Fig. 12) were much the same at all site-groups with the highest densities at the lowland sites. If they had been included in the inverse analysis they would most probably have been incorporated in group 3. Also shown in Fig. 12 are the mean densities of all the taxa at each site-group; these indicate there was less than an order of magnitude difference in density between site-groups. Finally, Fig. 12 and Table 14 suggest again that the sandy sites were depauperate versions of the cobble sites.

General Biological Features of the Site Groups

The differences in mean number of taxa per site between site-groups is clearly seen in Fig. 13. Throughout the study the cobble sites (groups B and D) had about 50% more taxa than either sandy (group A) or lowland (group E) sites. Group C (site 28) had only a slightly richer fauna than groups A and E, but it was most closely associated with groups B and D in the site classification (Fig. 10). The separation of groups B and D was partly due to the absence or scarcity of taxa in one group when compared with the other. These differences were particularly marked for the Plecoptera. Twelve species of stoneflies which commonly occurred in group B, were absent or rare in group D, while all such species found in group D commonly occurred in group B. Fig. 13 also re-emphasises the idea that sandy sites were depauperate versions of cobbles sites and this is confirmed in Table 15. Only 20 taxa were restricted to sandy sites while 127 taxa were restricted to cobble sites out of a total of 308 taxa collected during the study.

Table 15. Number of taxa in the major invertebrate groups collected only at sandy sites (1), only at cobble sites (2), and total collected during the study.

Invertebrate group	(1)	(2)	(3)
Ephemeroptera	0	8	29
Diptera(excl. Chironomidae)	6	25	51
Chironomidae	4	18	49
Coleoptera	3	21	48
Trichoptera	3	41	76
Plecoptera	2	6	26
Others	2	9	29
Total	20	127	308

Seasonal trends in the mean number of taxa were also evident, particularly in groups B, C and E (Fig. 13). In these groups maximum numbers of taxa were recorded during the colder months (May and August) and minimum numbers in the warmer months (November and February). Similar trends were shown by groups A and D but both lacked increases in taxa during the second winter; the absence of a second August sampling may have contributed to this.

The distinction between site-groups, based on the mean density of invertebrates per sample (Fig. 14) is also clear. On average groups B and D had approximately twice the faunal density of groups A and C. Group E showed the largest variations in density which were mainly due to two taxa: *Cheumatopsyche* sp. 1 and *Calopsectra* sp. 1. Generally, the same seasonal trends were apparent as in Fig. 13: higher densities occurred during the colder months and lower densities in the warmer months.

The mean number of taxa per site in each of the major invetebrate groups for each site-group is shown in Table 16. For all invertebrate groups, site- groups B and D had the highest mean number of taxa while site-groups A and E had the lowest; group C was usually intermediate. Of the insects, Chironomidae were the most diverse and the Plecoptera the least diverse; the Ephemeroptera, Trichoptera, Coleoptera and the non-chironomid Diptera were intermediate.

The relative abundance of the major invertebrate groups within each site- group is indicated by percentage abundance (Table 16). In all site-groups chironomids were numerically dominant forming from 23.2% of the fauna in group C to 43.3% in group E; ten of the 19 taxa in

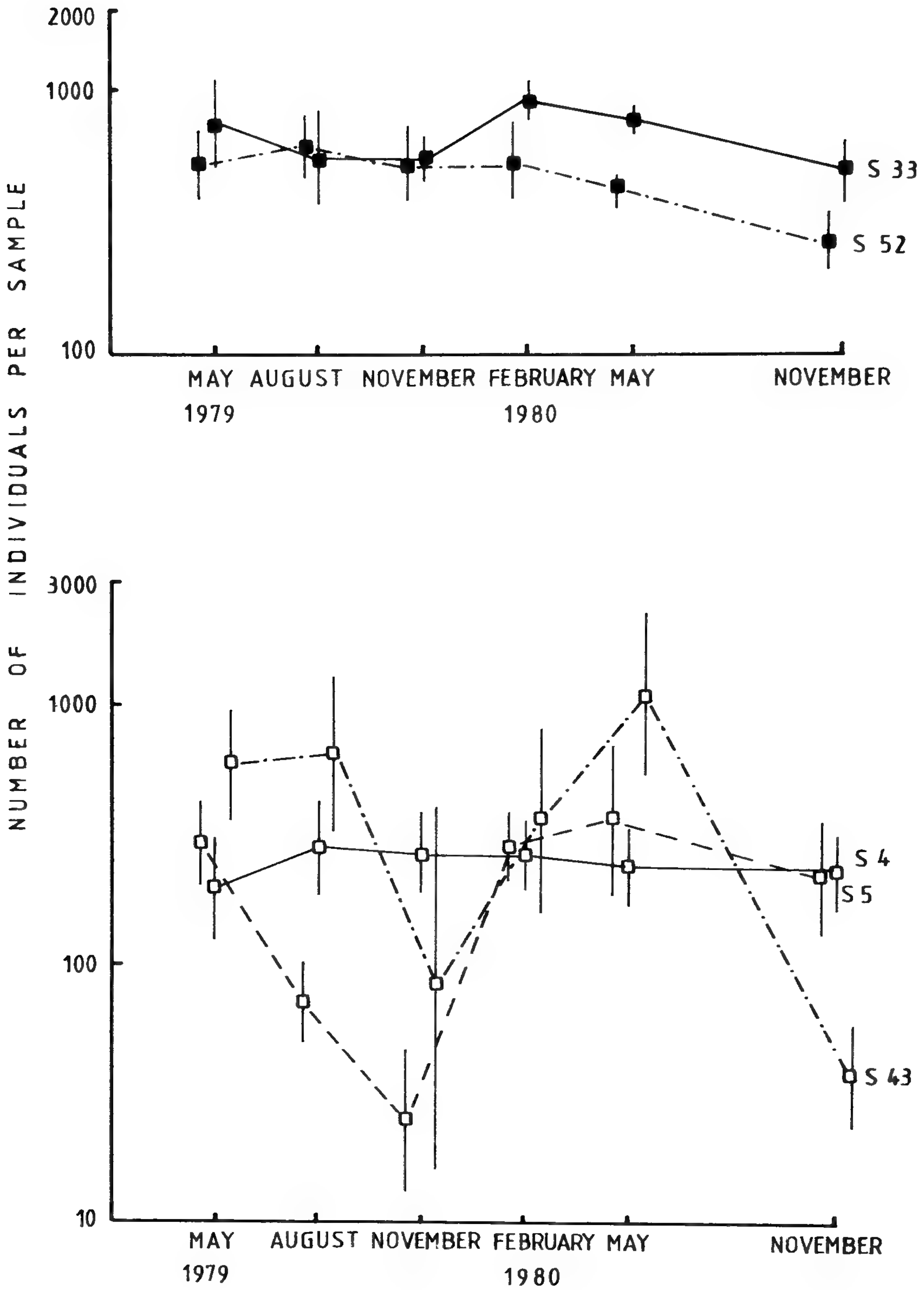


Fig. 8. Mean density and 95% CLs during the study at 5 sites.

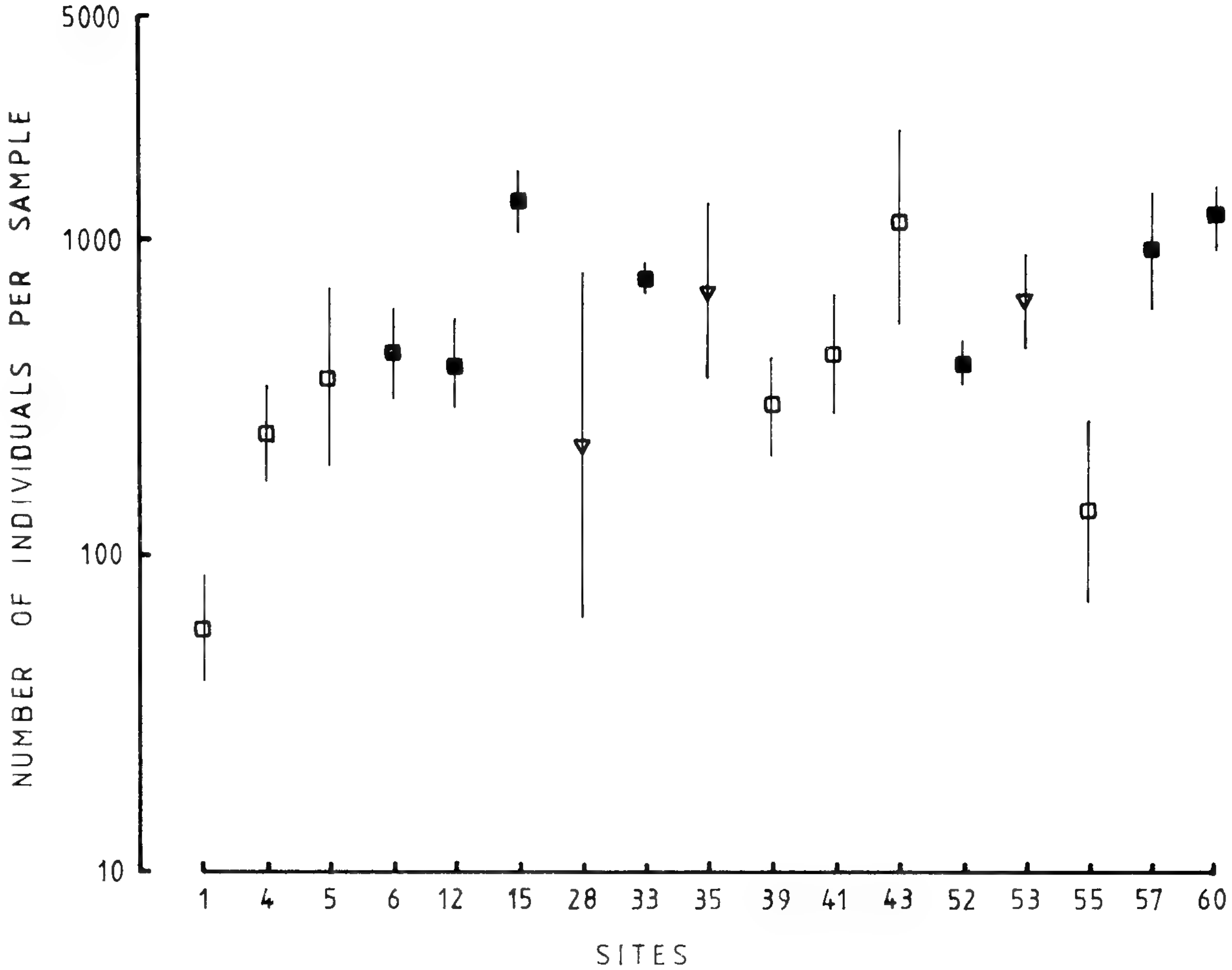


Fig. 9. Mean densities with 95% CLs for all sites from the May 1980 sampling trip. Substratum is indicated in Fig. 6.

Table 16. Percentage abundance of the major invertebrate groups and the mean number of taxa per site (in parentheses) for each site-group. Unidentified taxa were excluded.

Site-groups	A	B	C	D	E
Site	1, 4, 5, 39, 55	6, 12, 15, 33, 52, 53	28	41, 60	35, 43, 57
Ephemeroptera	7.1 (3.2)	20.6 (5.3)	18.7 (3.7)	18.4 (7.8)	6.5 (5.4)
Diptera (excl. Chironomidae)	5.7 (5.2)	8.4 (8.8)	5.1 (6.2)	10.4 (6.6)	3.5 (4.8)
Chironomidae	34.8 (9.8)	23.2 (13.4)	30.4 (11.3)	38.0 (13.6)	43.3 (12.1)
Coleoptera	25.6 (4.1)	19.5 (6.3)	15.5 (5.0)	7.5 (7.8)	5.6 (3.5)
Trichoptera	1.9 (3.0)	16.3 (10.0)	5.4 (6.0)	9.8 (12.4)	7.8 (5.5)
Plecoptera	3.8 (2.8)	3.7 (6.4)	16.0 (4.7)	1.6 (3.3)	0.3 (1.6)
Oligochaeta	16.6	11.6	8.0	9.431.5	
Others	4.4 (2.6)	3.0 (2.2)	1.0 (1.0)	4.9 (4.0)	1.6 (1.8)
Mean number of individuals per sample	214	471	217	941	541

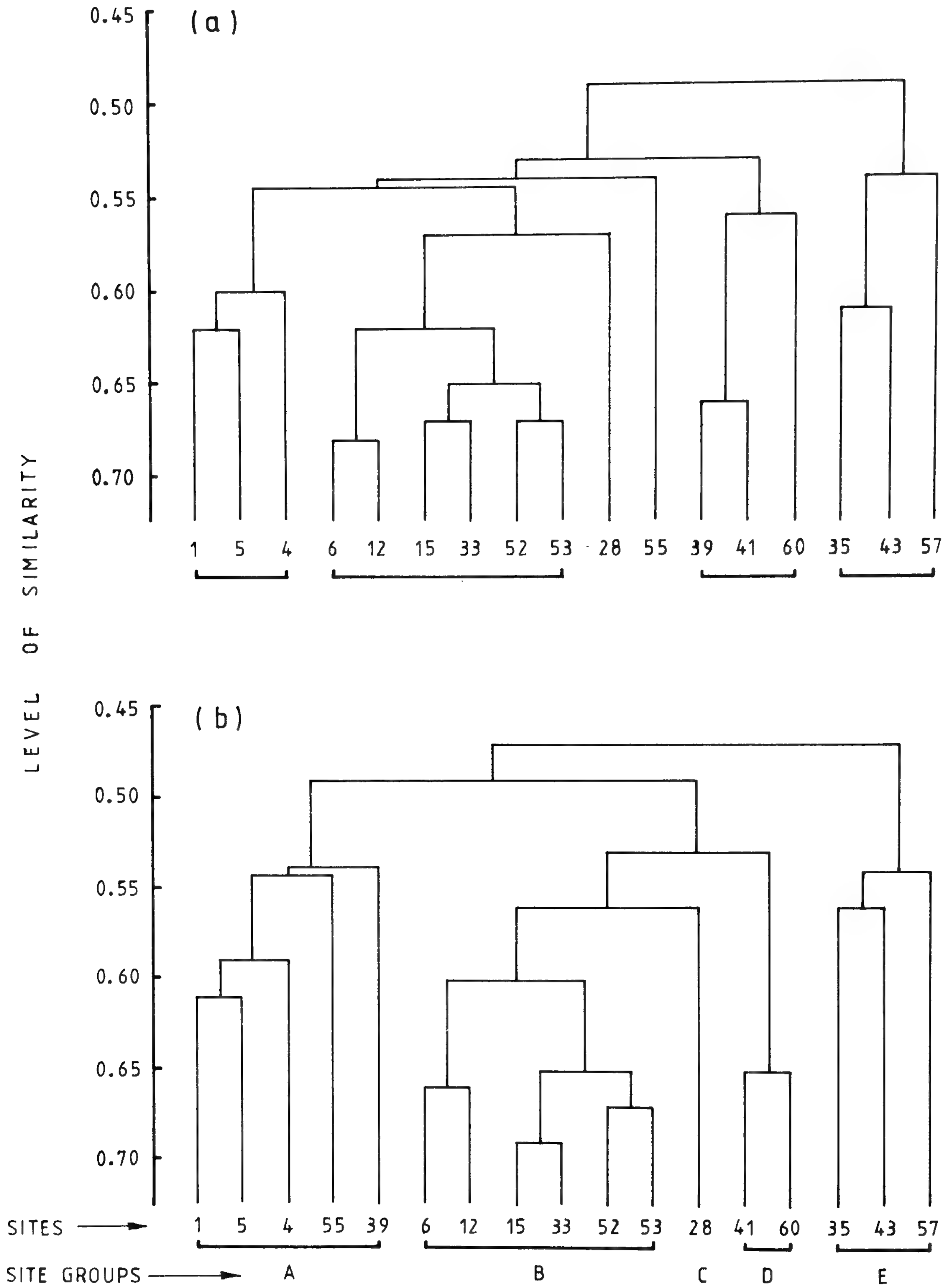


Fig. 10. Classification of the sites based on Sorensen's index (a) and Czekanowski's index (log data) (b) for the combined data from all samples. The brackets indicate the grouping of sites.

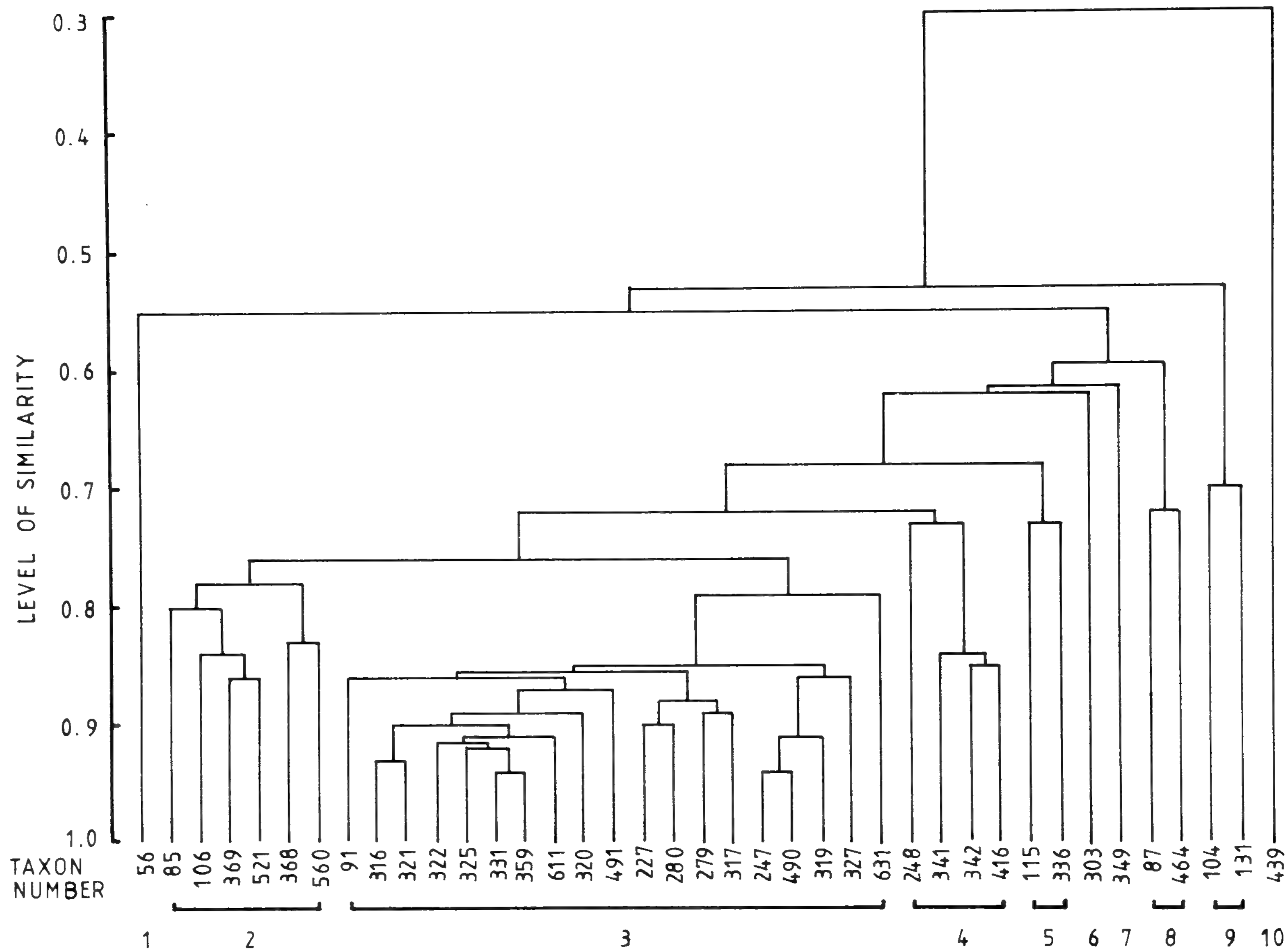


Fig. 11. Inverse classification of the 39 common taxa using Czekanowski's index (log data). The taxa groups are indicated by brackets and numbered.

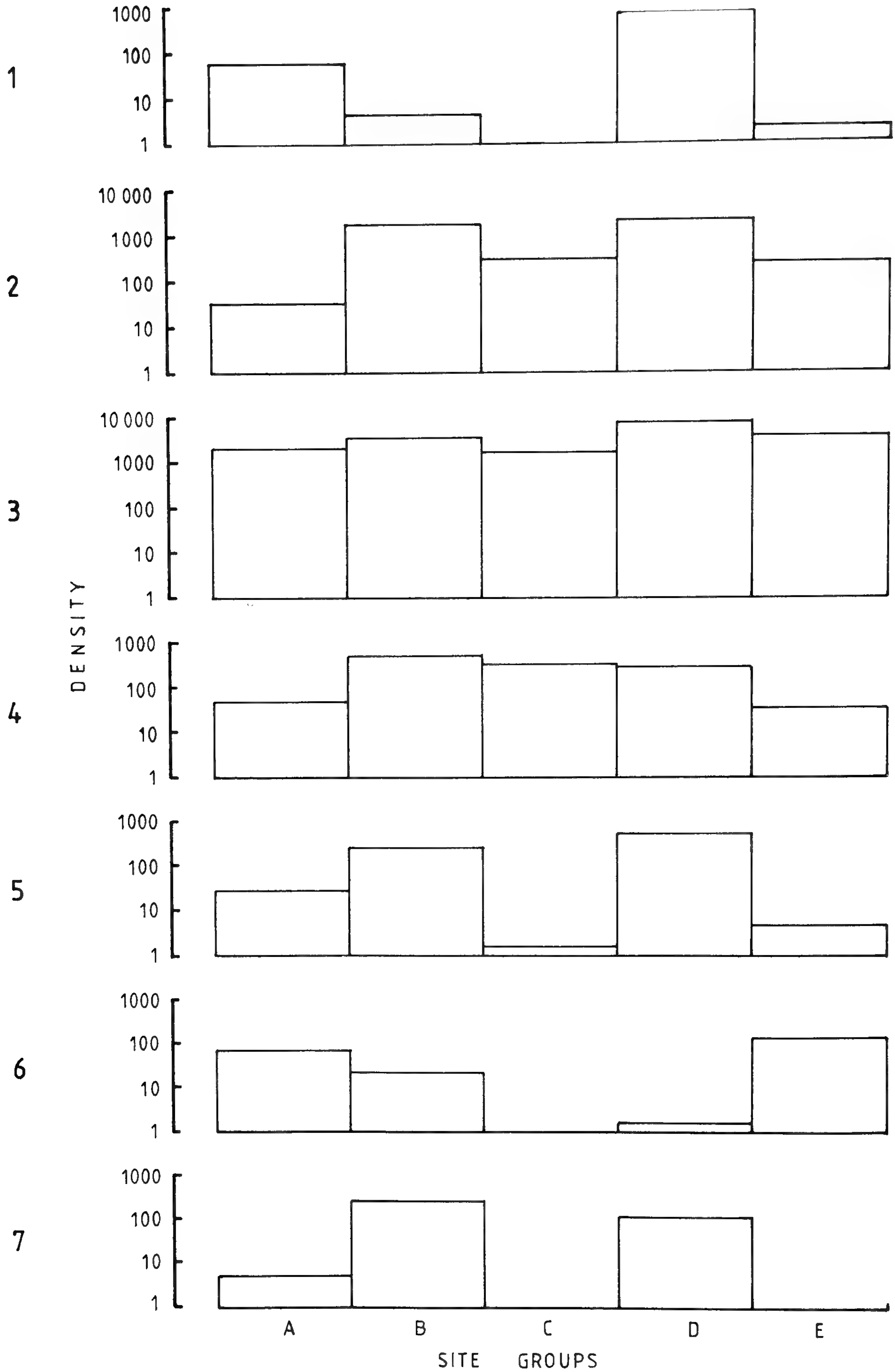


Fig. 12. Mean density (numbers of individuals per square-metre) of the fauna in each of the taxa groups (1–10) for each of the site groups (A–E). Also shown are the mean densities of the Oligochaeta and all taxa (on an arithmetic scale) at each site group.

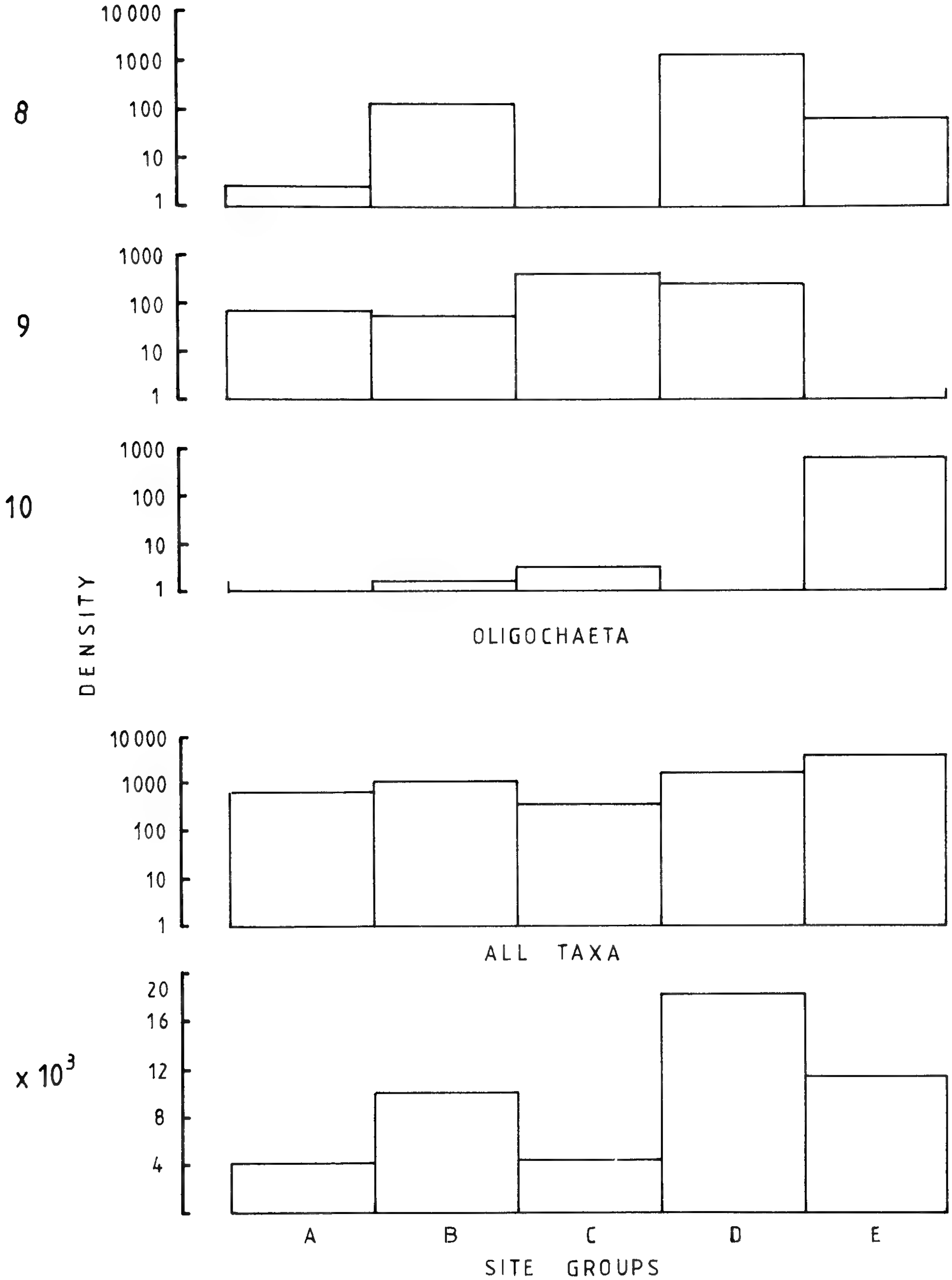


Fig. 12. (continued).

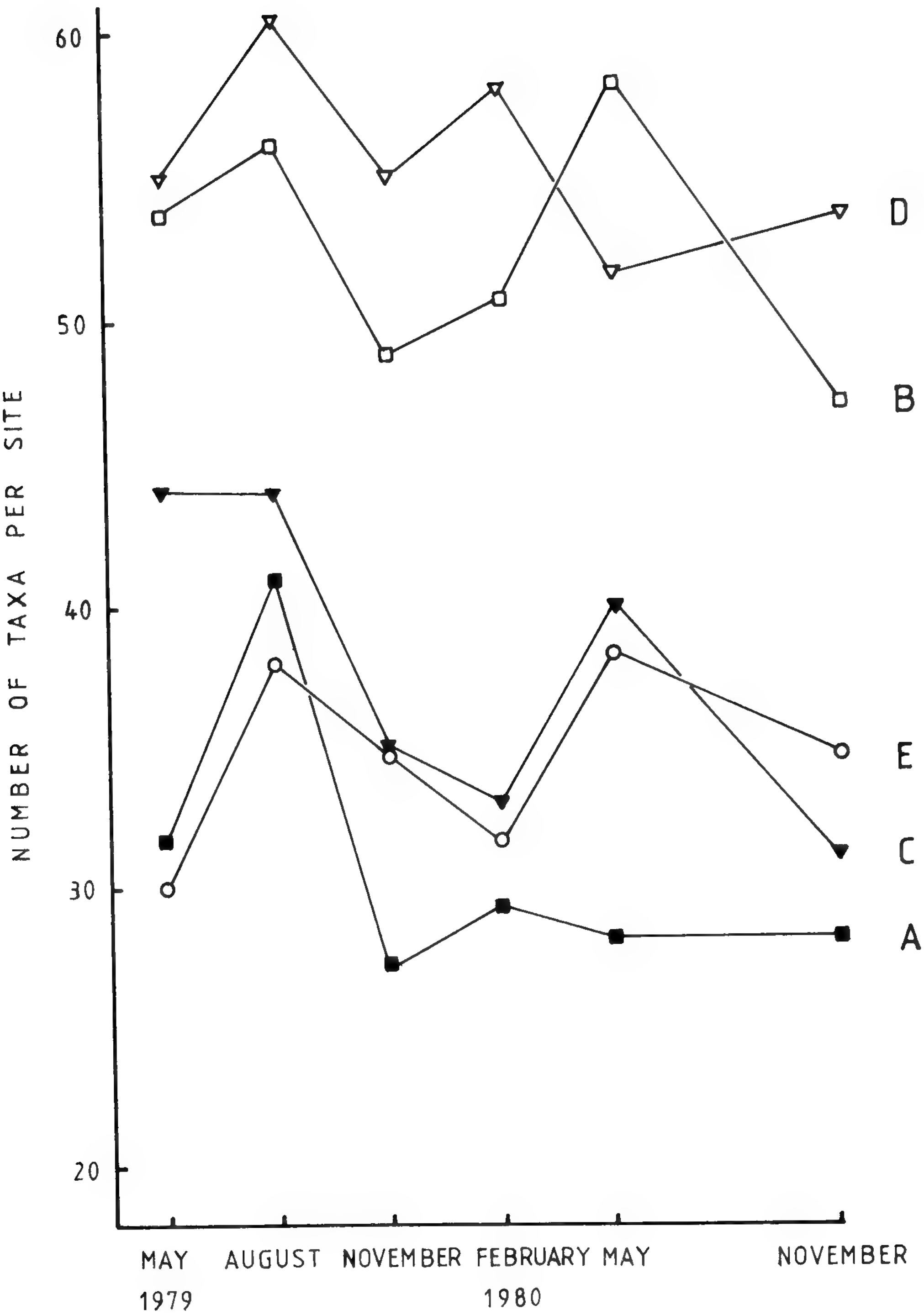


Fig. 13. Mean number of taxa for each site group (A–E) on each visit.

taxa group 3 (the most widespread group; Table 14) were chironomids. Coleoptera reached their highest percentage abundance in the northern catchment (site-groups A, B and C) but in terms of absolute abundance the five common coleopteran taxa (Table 14) were more or less equally abundant at all sites. Ephemeroptera formed a high percentage of the fauna at site groups B, C and D; five of the eight common ephemeropteran taxa (Table 14) were included in taxa groups 2, 5 and 9 which were most abundant at these largely cobble sites. The non-chironomid Diptera and Trichoptera formed lower percentages of the fauna at most site groups; both were less well represented at sandy sites (group A) than at cobbles sites (groups B and D). Plecoptera, which prefer cooler conditions, were poorly represented at all site-groups except the cold site- group C. The oligochaetes had a high percentage abundance (31.5%) only at the lowland sites (group E).

The seasonal changes in the total numbers of taxa in the major invertebrate groups (except Chrionomidae) are shown in Fig. 15. All these invertebrate groups show, with differing degrees of clarity, the same seasonal trends outlined above; the Plecoptera show this particularly clearly. Maximum values were often obtained in August 1979 but the absence of a visit in August 1980 tended to obscure the trend of the following year. Differences in

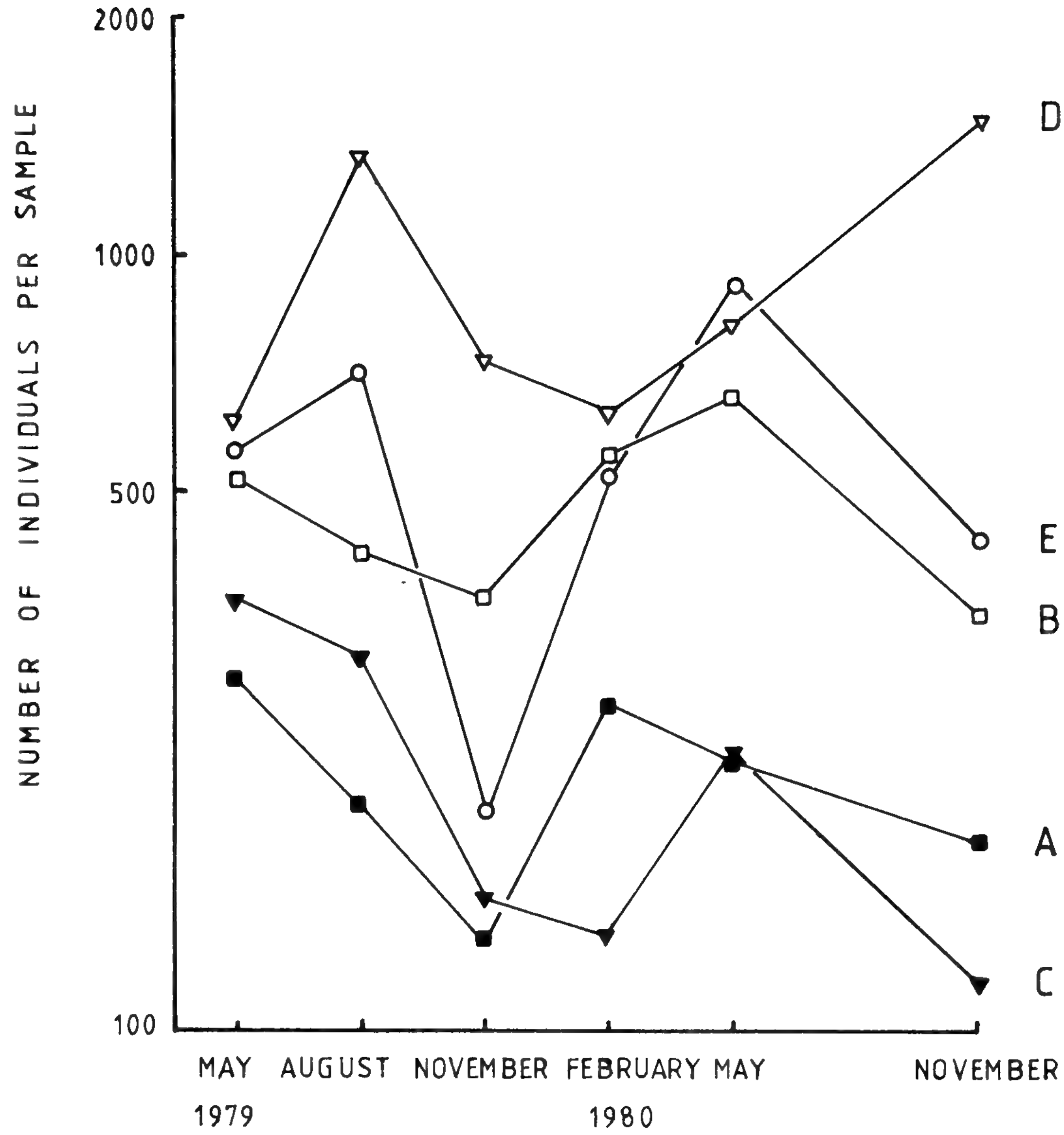


Fig. 14. Mean densities of invertebrates for each site group (A–E) on each visit.

total numbers of taxa between site groups (Fig. 15) are to some extent a reflection of the differing number of sites within each site group as well as the differences between site-groups.

The Chironominae were the most diverse subfamily of chironomids (35-50% of the taxa at all site groups) on all but the August visit when they formed between 15-25% of the chironomid taxa (Fig. 16). On this visit the number of taxa in the 'others' category (Tanypodinae, Aphroteniinae, Diamesinae and Podonomiinae) increased to form 35-50% of the chironomid taxa. The number of Orthocladiinae taxa remained fairly constant throughout the study forming about one-third of the chironomid taxa at all site groups (Fig. 16). Seasonal trends were not as apparent as with the other invertebrate groups (Fig. 15) but there was a slight decrease in the number of taxa in February.

Seasonal changes in the mean densities of most major invertebrate groups were evident (Fig. 17) but were not as marked as those for the total fuana (Fig. 14). The Plecoptera, at all site groups, showed a consistent decrease in abundance during the summer. This was probably due to emergence of adults. The Ephemeroptera, Trichoptera and Coleoptera also generally had their lowest densities in the warmer months (November, February), probably as a result of summer emergence, whereas the non-chironomid Diptera and the Oligochaeta showed little consistent seasonal fluctuation in density between site-groups. Site-groups B and D recorded the highest densities of Ephemeroptera, Colepotera, Trichoptera and non-chironomid Diptera. The Plecoptera were most abundant at group C and the Oligochaeta most abundant at group E, as in Table 16.

The Chironominae were usually the numerically dominant chironomid group throughout the study forming between 13% (group C, November 1980) and 79% (group E, May 1980) of the chironomid fauna (Fig. 18); on average they formed 53% of the chironomid fauna. The Orthocladiinae formed 36% of the chironomids and varied between 8% (group D, May 1980) and 61% (group D, November 1980). The 'others' category usually formed 11% of the fauna but at some depauperate sites they formed a much larger portion of the fauna (60% at group C, November 1980). At site group A, with the exception of the May 1980 sampling, the Orthocladiinae formed more than 50% of the fauna while the Chironominae were consequently reduced in numbers.

Seasonal trends were fairly clear with all sites groups

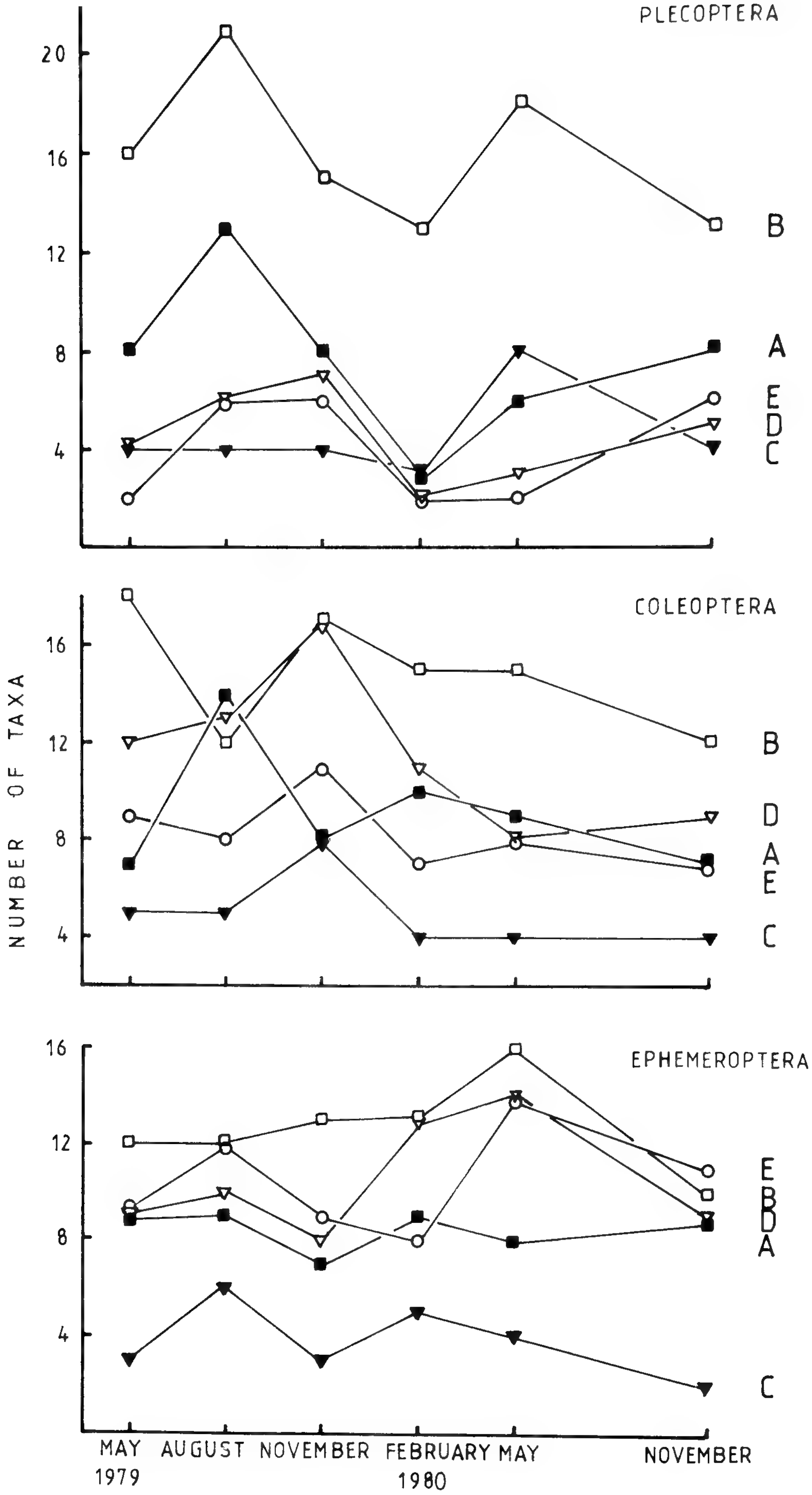
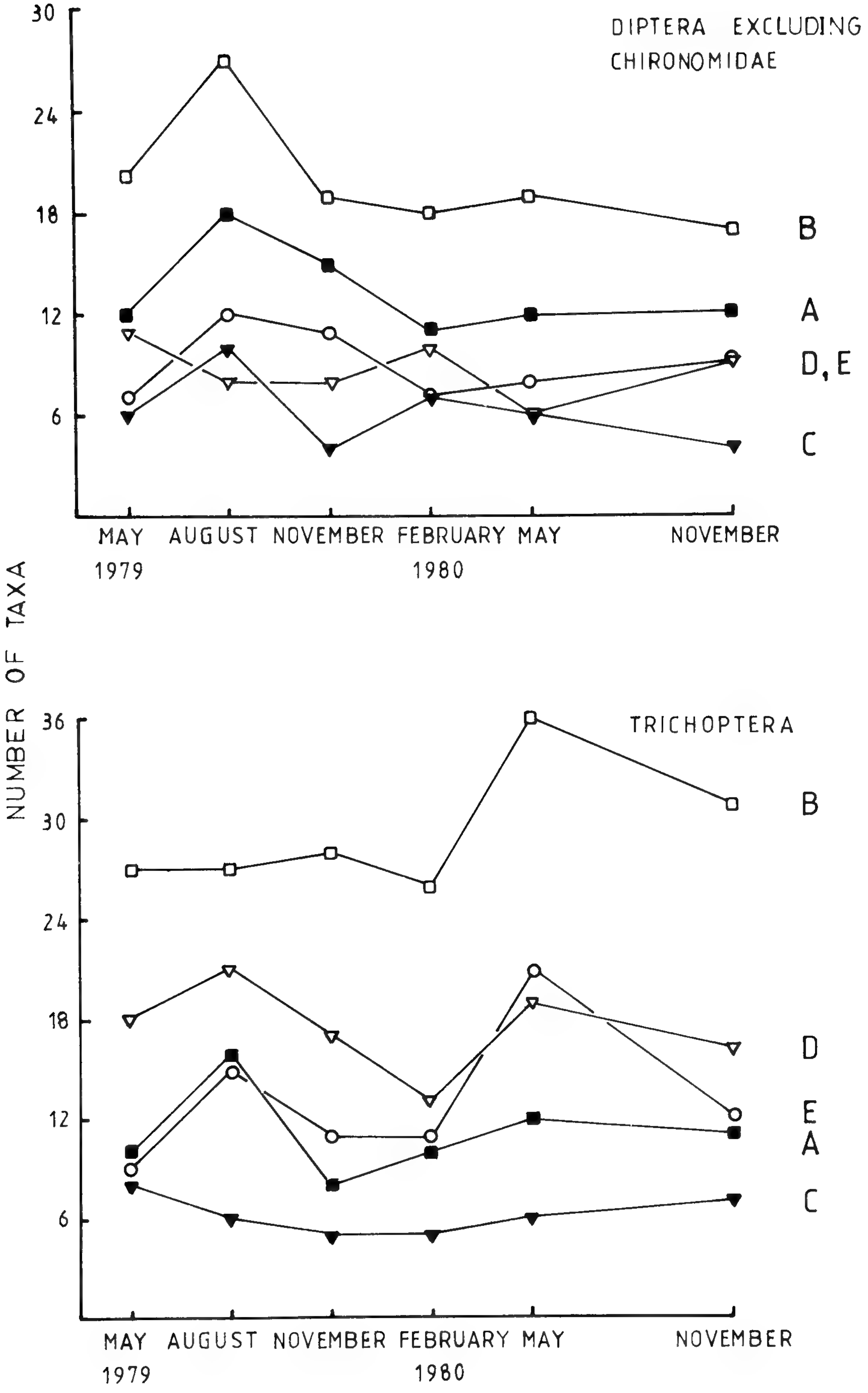


Fig. 15. Total number of taxa in each of the major invertebrate groups for each site group (A–E) on each visit.



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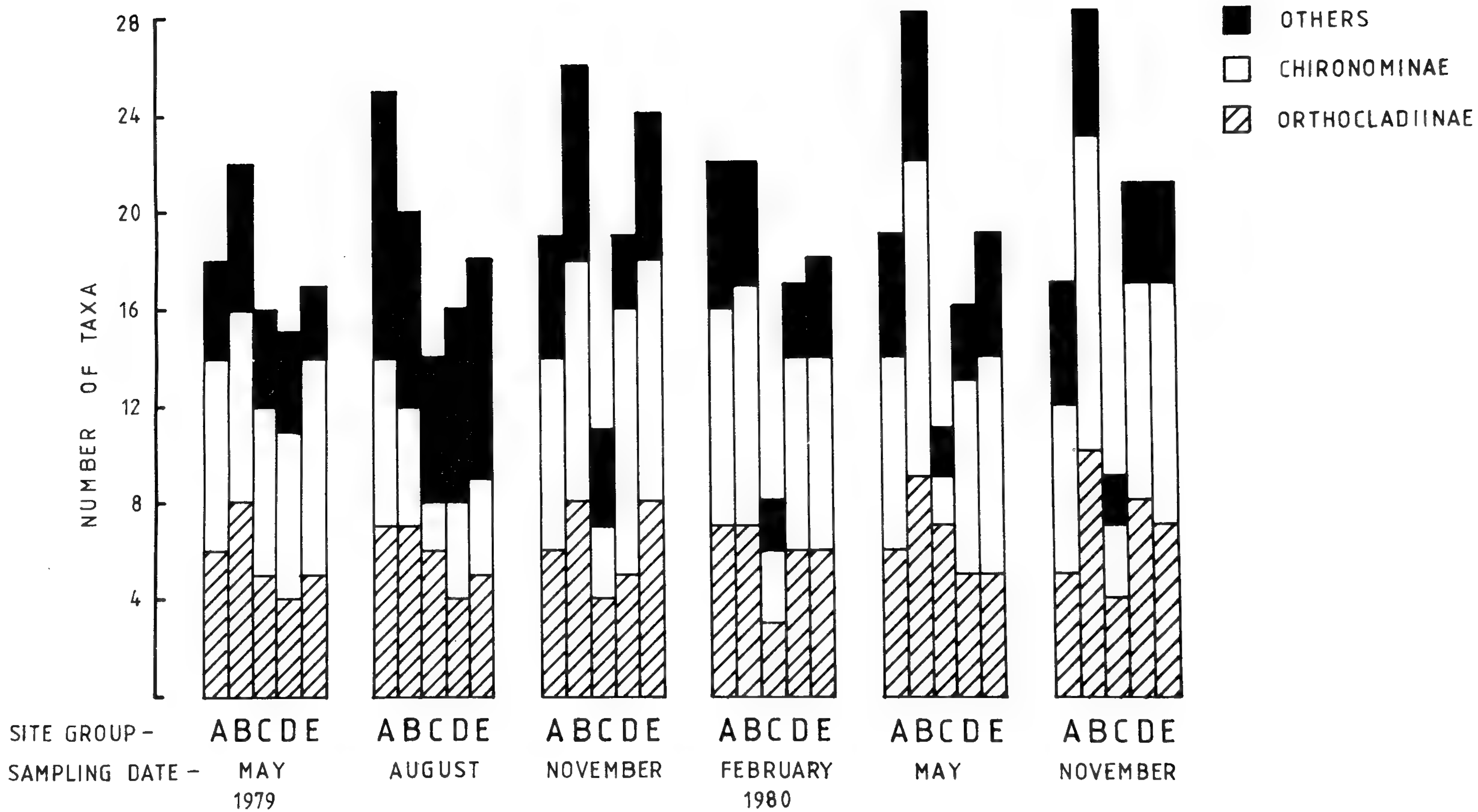


Fig. 16. Total number of taxa in the major chironomid groups for each site group (A–E) on each visit.

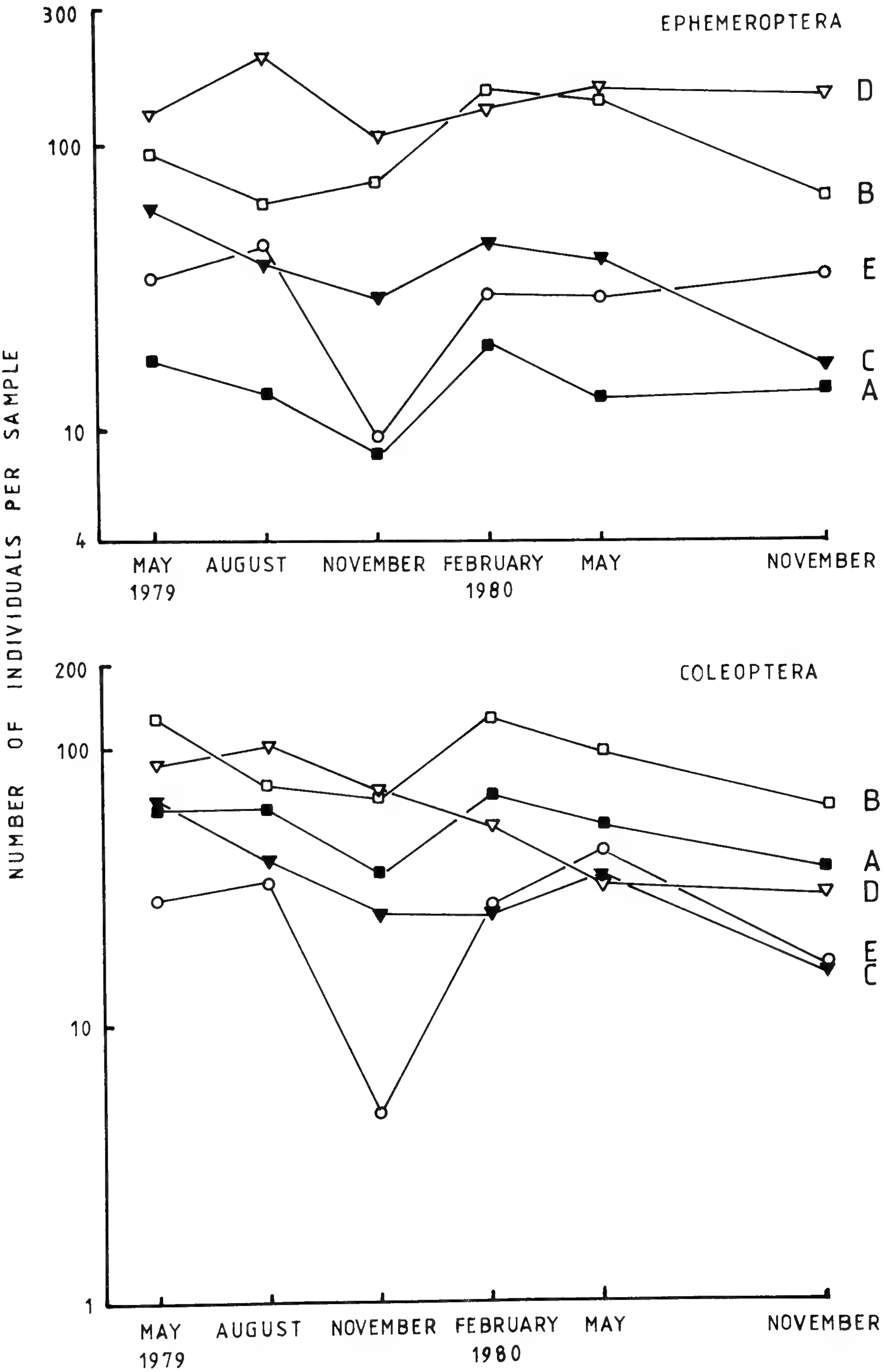


Fig. 17. Mean densities of the major invertebrate groups for each site group (A–E) on each visit. Confidence limits are similar to those already described (Table 11) indicating that significant differences exist between the maximum and minimum densities of most invertebrate groups with the occasional exceptions of site groups A and C.

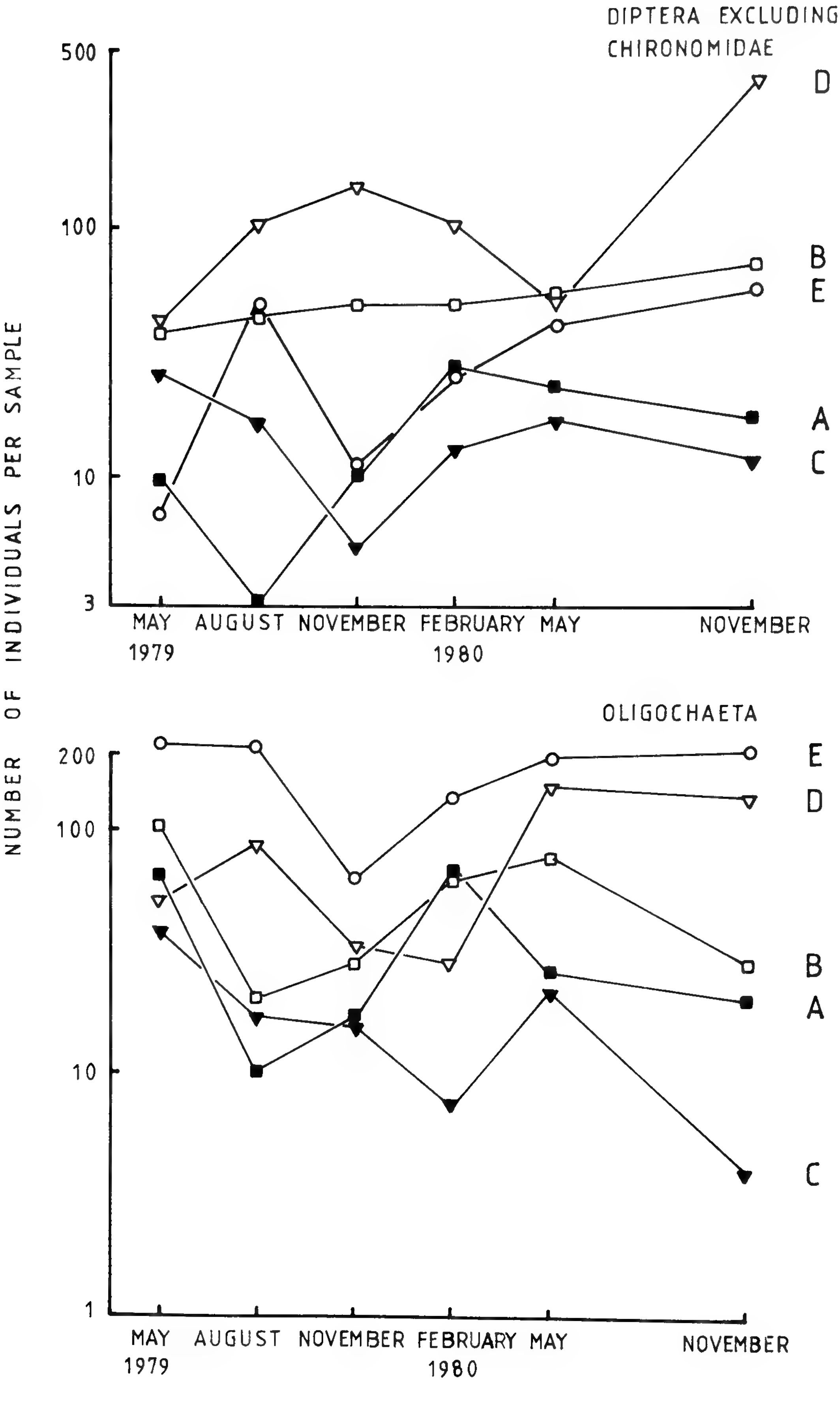
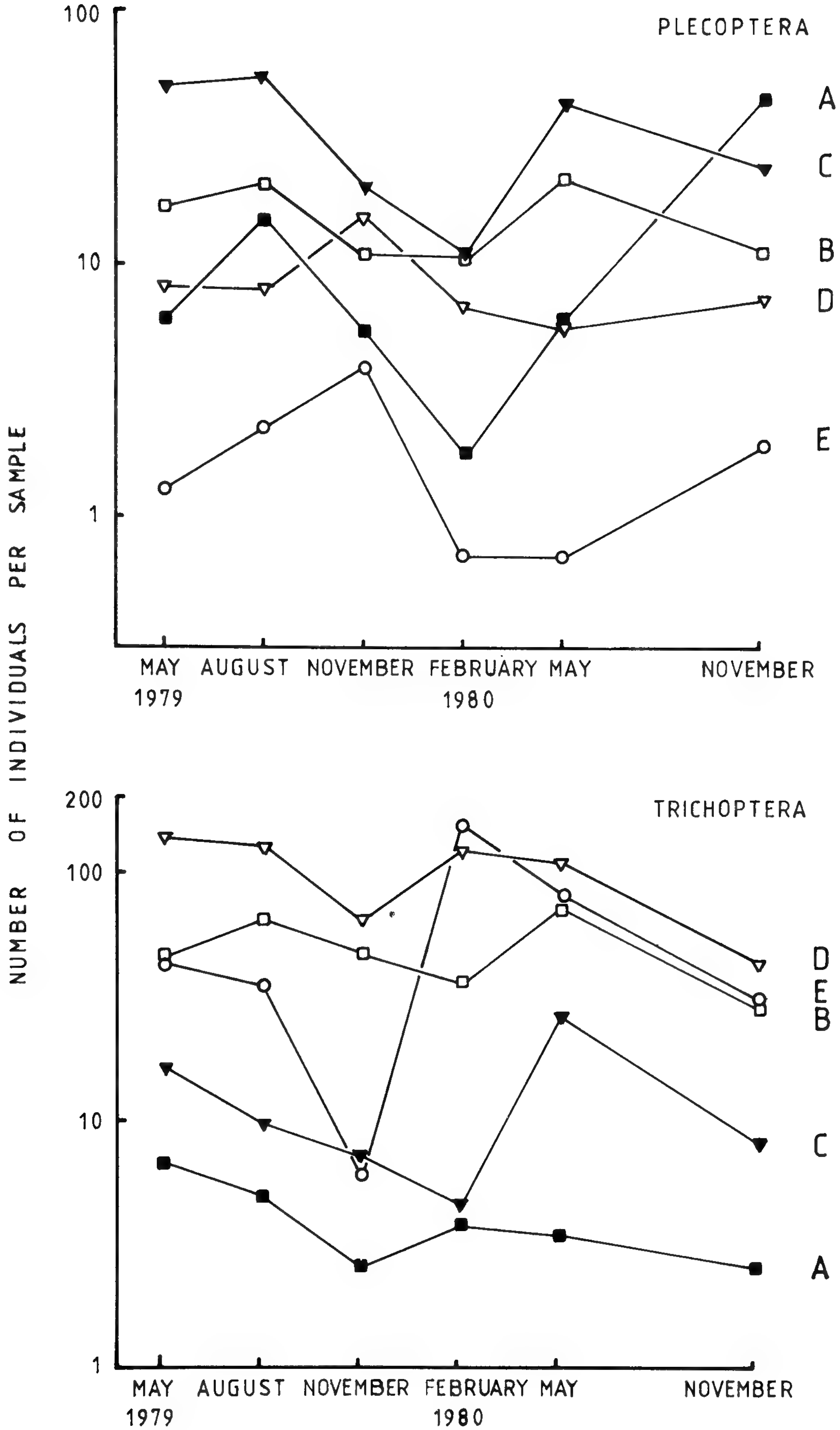


Fig. 17. (continued).



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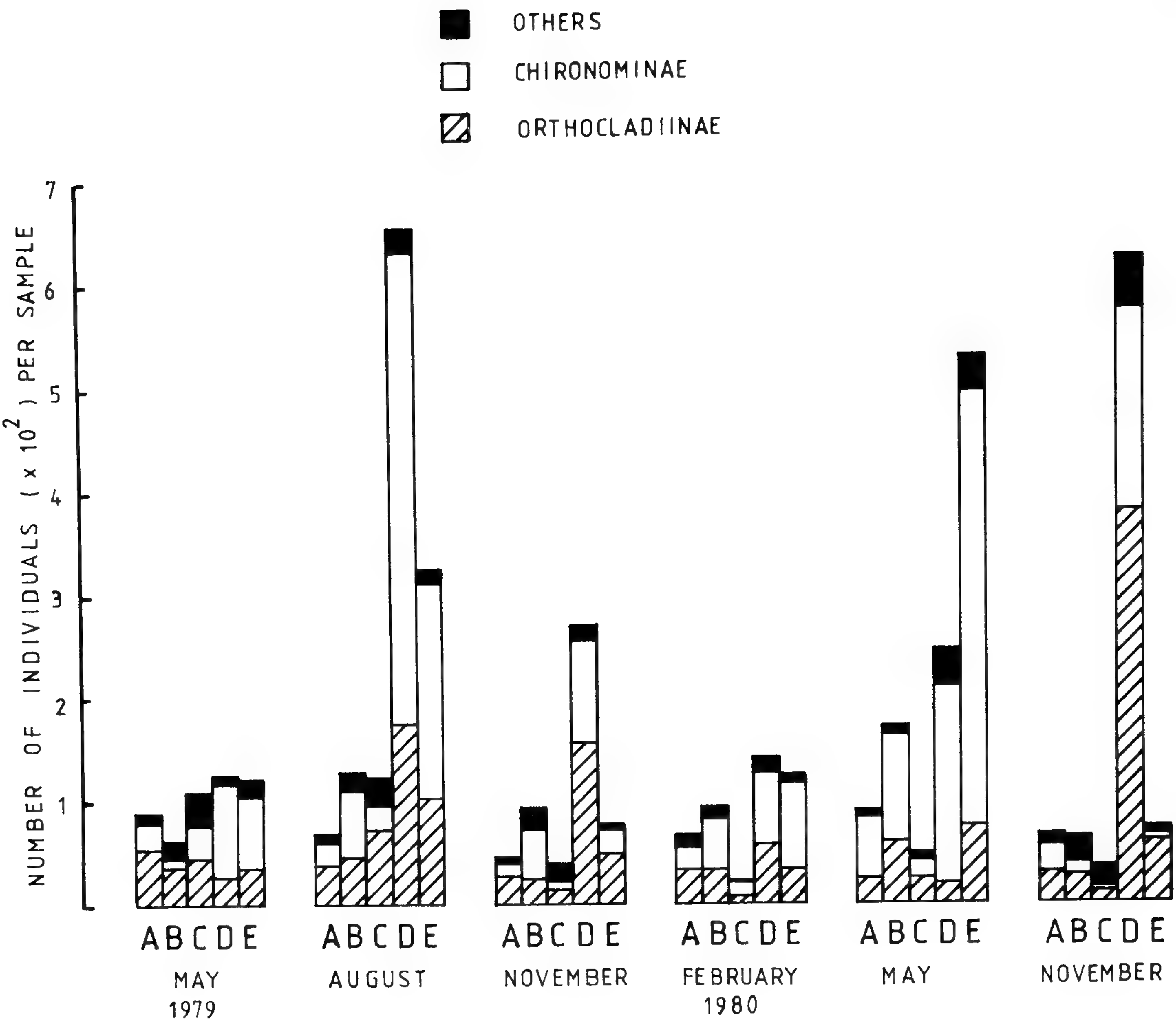

Fig. 18. Mean densities of the major chironomid groups for each site group (A–E).

Table 17. Physical and chemical characteristics of the site-groups (Fig. 10b). Unless otherwise indicated, values given are means.

Site-groups	A	B	C	D	E
Temperature mean and (range)					
May 1979	8.6 (6.9-10.8)	7.9 (6.8-9.2)	5.6	8.8 (8.5-9.0)	10.8 (10.5-11.2)
August 1979	6.9 (5.3-8.7)	5.6 (4.1-6.8)	2.3	7.6 (7.5-7.7)	7.8 (7.3-8.6)
November 1979	10.9 (7.9-13.2)	9.9 (8.5-13.5)	5.7	12.9 (12.4-13.4)	15.1 (15.0-15.3)
February 1980	13.6 (10.2-17.1)	11.8 (10.1-14.2)	8.0	16.1 (14.4-17.8)	18.9 (18.5-19.2)
May 1980	9.5 (8.7-11.5)	9.1 (7.4-10.5)	5.8	9.2 (8.7-9.6)	11.2 (10.6-12.4)
November 1980	16.0 (14.0-18.7)	14.9 (13.0-17.2)	12.5	16.9 (14.8-18.9)	19.8 (18.5-21.4)
Overall mean	10.9 (5.3-18.7)	9.9 (4.1-17.2)	6.7 (2.3-12.5)	11.9 (7.5-18.9)	13.9 (7.3-21.4)
Altitude (m)	294	346	930	200	57
Width (m)	5.9	7.8	6.0	3.8	7.8
Discharge (m^3s^{-1})	0.6985	1.1290	0.5697	0.1231	1.2781
Water velocity (ms^{-1}) mean & (Range)	0.30 (0.05-0.58)	0.51 (0.09-2.70)	0.39 (0.05-0.82)	0.29 (0.04-0.94)	0.37 (0.04-1.74)
Organic content (g/sample)	1.568	0.788	1.221	0.935	0.968
Substratum particle size (mm)	1.10	47.84	20.84	44.03	16.22
Description of substratum	sand	cobble	mixed	cobble	sand, cobble, mixed
pH	7.0	7.1	7.2	7.3	7.5
Conductivity (mSm^{-1})	7.8	4.4	3.1	17.6	11.8
TDS (mgl^{-1})	60.2	37.3	32.7	115.0	71.8
SS (mgl^{-1})	21	22	10	11	19
TOC (mgl^{-1})	8.2	16.8	43.3	3.1	4.7
Total phsophate ($mgl^{-1}PO4$)	0.074	0.061	0.079	0.053	0.021
Total nitrogen ($mgl^{-1}N$)	0.499	0.436	0.355	0.258	0.526

showing, to a greater or lesser degree, a reduction in density in summer. The density of chironomids was more constant at site-groups A, B and C than at groups D and E which showed much larger fluctuations. These fluctuations were mainly due to three taxa - *Rheotanytarsus* sp. 1 (group D, August 1979), *Calopsectra* sp. 1 (groups D and E, August 1979; group E, May 1980) and *Cricotopus sp.* 1 (group D, November 1980).

Physical and Chemical Features of the Site Groups

The major physical and chemical factors showed clear differences between the site-groups (Table 17). As expected, some factors were clearly interrelated, e.g., temperature varied inversely with altitude and width varied directly with discharge.

Sites in Group A had the highest mean value for organic content of substratum and the smallest mean particle size. As outlined earlier, the high levels of organic matter might have been related to the low mean water velocities (0.30 ms^{-1}) at sites in this group. However, group D which comprises two cobble sites had the lowest mean velocity (0.29 ms^{-1}) (mainly due to the presence at these sites of slow flowing pools) and yet did not have high levels of organic matter. This implies that both water velocity and substratum influenced the level of organic matter retained in the stream bed, with sand being a more effective trap for organic particles than cobbles.

Sites in groups B and D differed in a number of factors: temperature, water velocity, discharge, TOC, conductivity and TDS. The differences in the last two factors probably resulted from geographical differences as all the sites in the Strzelecki Ranges showed high values for these and other related measurements (Table 8). The streams in group B were larger, faster flowing, cooler and had slightly higher levels of TOC than those in group D.

Cold temperatures were the major distinguishing feature of the site in group C. This site also recorded the highest mean value of TOC but as TOC was measured only once this result needs to be treated with caution. However, the presence of many logs in the river upstream of this site (more than at any other site) could have contributed to the high levels of TOC.

Group E contained sand, cobble and mixed sites thus accounting for the low mean particle size. Other distinguishing features of sites in this group were warm temperatures and high values for discharge, conductivity and TDS, all of which are typical of lowland rivers.

Discussion

Comparison with Other Studies

One problem encountered in this survey was that the taxonomy of many groups of Australian aquatic invertebrates is poorly known; in particular the immature stages of many groups have not been associated with their adults. Thus we could not always be sure whether we were dealing with single species or with groups of closely related species particularly with some families of Trichoptera and Chironomidae.

Despite these limitations in taxonomic discrimination and in contrast to the known paucity of the Australian freshwater fish fauna (McDowall, 1980) and benthic invertebrates in lakes (Timms, 1980), this study and others studies, e.g., the Thomson River surveys by Malipatil and Blyth (1982) and Davey et al. (1982), indicate a diverse macroinvertebrate fauna for more or less undisturbed permanent rivers in eastern Victoria. A total of 308 taxa (with mites and oligochaetes treated as single taxa) were collected during this study, with average densities ranging over two orders of magnitude, from 500 individuals m^{-2} to 50 620 m^{-2} (Table 10). Malipatil and Blyth (1982), in a qualitative survey of the Thomson River which covered many diverse habitats, found 528 taxa although they did not identify Trichoptera and Chironomidae; 275 taxa were found at six sites sampled quantitatively by Davey et al. (1982). Towns (1979), studying a small (34 km^2 catch-

ment) northern New Zealand kauri forest stream, collected 144 taxa, almost three times the maximum number previously recorded from a New Zealand stream. He attributed this to the failure in previous studies to treat the entire macroinvertebrate fauna at species level.

These findings are comparable with those found by similar studies in the northern hemisphere. A three year survey of the riffle fauna at 14 sites on the River Wye, U.K. (Brooker and Morris, 1980), a river similar in length and drainage area (4,183 km^2) to the LaTrobe River (4,600 km^2), found 227 taxa with total macroinvertebrate densities ranging from 520-22,020 m^{-2}: the fauna was typical of that for this habitat in the U.K. If we allow for use of a coarser mesh (440 microns) and a smaller sampling effort by Brooker and Morris than in our study the two rivers appear to support similarly diverse faunas.

The composition of our fauna (Table 12) was generally similar to that found by Davey et al. (1982) for the Thomson River and Brooker and Morris (1980) for the River Wye. Chironomids were the dominant group forming an average of 32% of the fauna at each site, a larger portion than found in the River Wye (23%). Towns (1979) reported that in his New Zealand stream the Diptera as a whole, with chironomids in particular, were poorly represented with fewer species than were found incomparable studies in the northern hemisphere.

The number of species of stonefly is comparable with that found in rivers in the U.K. (Armitage et al., 1974; Brooker and Morris, 1980); though they contributed less to total numbers (4%) than in the River Wye (11%). Similarly, the Trichoptera formed a smaller percentage of total numbers (7%) than in the River Wye (13%). However, we recorded 76 taxa of Trichoptera, many more than the 21 found by both Brooker and Morris (1980) and Armitage et al. (1974). Davey et al. (1982) found 68 taxa in the Thomson River while Towns (1979) described his New Zealand stream as being caddisfly rich (31 taxa).

Beetles formed an average of 18% of the fauna of each site mainly as a result of the abundance of the Elmidae. This family has often been reported as forming a substantial component of the stream fauna (Armitage et al., 1974; Brooker and Morris, 1980; Malipatil and Blyth, 1982). The Ephemeroptera formed an average of 14% of total numbers at our sites, less than that found in the River Wye (18%) and in other studies (Armitage et al., 1974; Towns, 1979); however, the number of Ephemeroptera taxa was comparable. Finally, Oligochaeta formed the same percentage of the fauna in the LaTrobe as in the Wye.

Changes in the benthic fauna of ostensibly undisturbed rivers have been related to changes in water chemistry. Egglishaw and Morgan (1965) found a significantly poorer fauna in water with a TDS less than 55-60 mgl^{-1}. TDS values for the Thomson river (Davey et al., 1982) and for most of the streams in the present study were all generally less than 55 mgl^{-1}, yet the macroinvertebrate fauna of these rivers cannot be considered depauperate. Only at the four sites in the Strzelecki Ranges, and site 57, did TDS exceed 55 mgl^{-1} (Table 8). Although these increases in TDS did not generally correspond to faunal differences between poor and rich sites, group D sites (from the Strzelecki Ranges) did have a richer fauna than all other sites.

Calcium levels are known to be related to the distribution of crustaceans and molluscs (Sutcliffe and Carrick, 1973; Williams, 1981). Morris and Brooker (1980) reported that the limpet *Ancylus* was not found at mean calcium concentrations below ca 3 mgl^{-1} and the mussel *Sphaerium*, *Gammarus* (Amphipoda) and *Asellus* (Isopoda) were restricted to sites with mean concentrations greater than ca 8 mgl^{1}. Although we collected crustaceans and molluscs at nearly all sites, only at the four Strzelecki sites and site 57 did mean calcium concentrations exceed 3 mgl^{1}. It is hardly surprising that Australian aquatic invertebrates are tolerant of low levels of calcium as, unlike much of Europe and North America whose waters are usually dominated by calcium and bicarbonate, Australian inland waters are dominated by sodium and chloride (Bayley and Williams, 1973).

Seasonal Changes in the Fauna

Seasonal cycles were clearly shown in the present study both for numbers of taxa and numbers of individuals (Figs. 13 and 14). These cycles generally conform with Hynes' (1970) schematic representation of the seasonal fluctuations in the macroinvertebrate fauna of temperate rivers in the northern hemisphere: maximum numbers occur in autumn and winter as a result of the hatching of eggs laid the previous summer and minimum numbers in spring and early summer as a result of larval mortality and emergence of adults. The life histories of Australian stream invertebrates are generally unknown. Only the Plecoptera in SE. Australia have been studied in any detail (Hynes and Hynes, 1975); they exhibited a lack of seasonal rigidity in growth and emergence, compared with Plecoptera in the northern hemisphere, and the durations of their life cycles varied from one year to three or four years. The fact that the seasonal cycles of our fauna were similar to Hynes' general scheme suggests that at least the durations of the life cycles of our fauna were probably comparable with those prevailing in the northern hemisphere.

The seasonal cycles of our fauna differ from those shown by the fauna in other studies in SE. Australia. Doeg and Blyth (1982) in a study of the Mitta Mitta River and Snowy Creek found minimum levels of both numbers of species and numbers of individuals in August and October and maximum levels in summer. Similar results were recorded by St Clair and Blyth (1979, 1981) for the same rivers, by Davey et al. (1982) for the Thomson River and by Towns (1979) for a small New Zealand stream.

Such results from the six sites on the Thomson River can best be compared with those from the six sites in group B which have substrata similar to those in the Thomson River. The catchments are adjacent, the Thomson being east of the northern cathcment of the LaTrobe; most of the taxa were common to both catchments; the work was carried out in the same laboratory using the same voucher system and collecting techniques (the Thomson study also used 30 cm deep cobble-filled baskets as artificial substrata); the same mesh size was used; collecting trips were within two or three weeks of each other and the sampling programmes covered the same years. Despite these similarities both studies produced quite clear but opposite seasonal cycles. The group B sites and the Thomson River sites exhibited a similar annual range in numbers of taxa and individuals, but the Thomson was the richer of the two rivers. The artificial substrata in the Thomson showed a more pronounced seasonal pattern with a greater annual range of densities.

The differences in seasonal cycles may be partly due to different temperature regimes. All but the most upstream Thomson River site experienced a greater range of temperatures with higher maxima than did the group B sites (maximum of 24-25 C compared with 20 C). However, our lowland sites (group E), which showed the same seasonal cycles in fauna as group B, experienced maximum temperatures comparable with those recorded in the Thomson (LVWSB, pers. comm.).

River Zonation

Many attempts (reviewed by Hynes, 1970; Hawkes, 1975) have been made to classify rivers into zones. The most widely accepted scheme is that developed by Illies (see Hynes, 1970) which proposes two basic zones: the erosional zone or rithron with turbulent flow and the depositional zone or potamon with more laminar flow. This basic separation was based principally on northern hemisphere rivers, but has been applied to tropical rivers and occurred in the Thomson River (Malipatil and Blyth, 1982).

Our site-groups (Fig. 10) can also be divided into those from the rithron (site-groups A, B, C and D) and potamon (group E). Malipatil and Blyth (1982) found three subdivisions within the rithron, but as we had fewer sampling sites on each river (maximum of four sites) such detailed analysis was not possible.

None of the major taxa-groups (groups 2, 3 or 4) from the inverse classification was confined to either the rithron or potamon. These groups were found either commonly throughout the catchment (group 3) or in greater abundance at the cobble sites (groups 2 and 4). The groups which consisted of single taxa or pairs of taxa all had restricted distribution with maximum abundances in one or two site-groups. Only *Cheumatopsyche* sp. 1 (taxa-group 10) was clearly restricted to the potamon, while taxa-groups 5, 7 and 9 were more or less restricted to the rithron. Malipatil and Blyth (1982) also found *Austrocercella mariannae* (taxa-group 9) was restricted to cold mountain streams.

Some authors have tried to use invertebrate families to characterize the rithron and potamon (Chutter, 19780; Hawkes, 1975; Williams, 1981). Bayly and Williams (1973) list families which are thought to characterise the two zones in Australia. While some families are very obviously associated with one zone the (Psephenidae and Blepharoceridae are clearly associated with the rithron because they adhere to rocks) such an approach is of limited value as many of these families commonly occur throughout both rithron and potamon in the LaTrobe catchment. Bayly and Williams (1973) and Williams (1981) listed the Leptophlebiidae, Baetidae, Simuliidae, Elmidae, Helodidae and Glossosomatidae among others as being associated with the rithron; yet all these families were represented in taxa-groups 2, 3 and 4 (Table 14) which were found throughout the catchment. Also in these taxa-groups were the Chironomidae and Leptoceridae both of which have been associated with the potamon (Bayly and Williams, 1973). If the associations of family with zone are indeed stricter in the northern hemisphere than those found here (Hawkes, 1975) then perhaps such families in Australia have radiated into a wider range of habitats as Towns (1979) suggested for these families in a New Zealand stream.

Thus, it is probably not possible or useful to define the potamon or rhithron precisely, as Hynes (1970) has already concluded, and numerical classification seems a more practical way of classifying sites along a river, particularly for a large amount of data. Furthermore, when a range of classificatory procedures produces the same or similar site-groups (as in this study) then such groups probably differ obviously.

Table 18. The percentage of taxa per site group in each feeding group (based on all samples). 'Others' include shredder/scraper, shredder/gatherer and scraper/gatherer.

Site-groups	A	B	C	D	E
Shredder	15	19	10	14	19
Scraper	16	16	13	12	13
Gatherer	18	14	23	18	18
Others	20	19	15	24	19
Filterer	11	14	18	12	18
Predator	18	14	18	16	11
Generalist	2	4	3	4	2
Number of taxa examined	61	69	40	50	46

Table 19. The percentage of individuals per site group in each feeding group (based on all samples). 'Others' are defined in Table 18.

Site-groups	A	B	C	D	E
Shredder	32	24	24	14	8
Scraper	9	25	17	13	4
Gatherer	43	20	27	16	39
Others	11	13	20	23	13
Filterer	3	13	7	30	29
Predator	2	4	3	3	2
Generalist	1	1	2	1	5
% of total fauna classifiable	44	44	45	48	36
Mean number of individuals	214	471	217	941	541

Feeding groups

An examination of the feeding habiats of macroinvertebrates provides an alternative perspective to that of taxonomic or numerical classification. Chessman (1981) examined the gut contents or observed the feeding of 100 taxa of macroinvertebrates from the LaTrobe River and assigned them to various feeding groups defined by Merrit and Cummins (1978). We collected 85 of these taxa which include 20 of the 39 common taxa (mostly those in the widespread taxa groups 2, 3 and 4). These data enabled us to assess the relative importance of the various feeding groups within each site-group.

There was little variation between site-groups in the percentage of taxa in each feeding group (Table 18); however, there were noticable changes in the percentage of individuals (Table 19). Shredders which eat large particles of organic matter e.g., leaves were reduced in importance at the lowland sites (group E); this corresponds with

a marked reduction in riparian vegetation at these sites compared with upstream sites. Scrapers which were also of reduced importance at sites in group E were most frequent at the upstream cobble and mixed sites (groups B and D) reflecting their adaptation for grazing upon periphyton adhering to solid substrata (Cummins and Klug, 1979). Filterers occurred at a high percentage abundance only at site groups D and E; as the lowland sites probably have a higher abundance of plankton than upstream sites, the distribution of filterers is partly understandable. Gatherers which primarily feed on small detrital particles (Cummins and Klug, 1979) were well represented at all site-groups despite differences in the levels of organic matter in the substrata (Table 17); this illustrates the limitations previously discussed in our measurements of organic content. Predators consistently formed a small portion of the fauna (2-4%), smaller than has been recorded elsewhere. Hawkins and Sedell (1981) found 10-40% of the fauna in four Oregon streams were predators while other studies (Anderson and Sedell, 1979; Williams, 1981) indicated that predators form 10-15% of the fauna.

Generally, it appears that the distribution of our fauna in the various feeding groups varied downstream with changing food supplies in much the same manner as predicted by previous studies (Williams, 1981). However, our sites spanned a narrower range of stream orders (only stream orders 2-5, Table 3) than is perhaps necessary to show marked differences in percentage representation.

Other Habitats

Although sand and cobbles covered the greatest percentage of the river bed at all our sites, other important habitats such as logs and leaf packs were present. These occupied far less of the bed.

Logs occurred at all sites and at some, e.g., site 28, were quite abundant. Only 17 taxa (10% of the total number of taxa collected from logs) were restricted to logs and only one of these, *Notriolus taylori* (Elmidae), was common occurring at five sites. It is significant that five of these 17 taxa were elmids, a family in which some species are known to be important wood gougers (Anderson et al., 1978; Anderson and Sedell, 1979). Animals feeding on woody debris are most likely to be utilizing the microbial flora associated with the surface layer (Anderson et al., 1978).

Leaf packs were present at all sites though never abundantly and were not included in samples. However, in the qualitative survey we found a rich fauna within the leaf packs but only a few species were restricted to this microhabitat.

The hyporheos was not sampled in this study; the depth of penetration with the Surber sampler was only 5-10 cm. Marchant et al. (1984) reported that at sandy sites in the lower reaches of the LaTrobe River about two-thirds of the fauna were located in the top 10 cm and that the fauna penetrated at least 30 cm. In cobble substrata fauna have been recorded at depths of up to 70 cm (Williams and Hynes, 1974; Davey et al., 1982) although the majority of the fauna were usually within 10 to 20 cm of the surface (Morris and Brooker, 1979; Hynes et al., 1976). Therefore it is likely that at both sandy and cobble sites fauna occurred at depths lower than were sampled. We have assumed that such underestimates were similar at all sites.

Conclusions

1. Faunal changes were mostly associated with changes in substratum and temperature (or altitude). The lowland sites (group E) were characterised by warm water temperatures. The higher altitude sites were clearly separated into the sandy sites (group A) and the cobble or mixed sites (groups B, C and D). Division between groups B, C and D appeared due to low temperatures (group C) or to differences in the concentration of dissolved solids (group B versus group D). The sandy sites were depauperate in numbers of taxa and density of individuals when compared with the cobble sites.
2. Maximum numbers of taxa or faunal density occurred during the winter in all site-groups. Such seasonal variation agrees with the general pattern found in the northern hemisphere.
3. The macroinvertebrate fauna as a whole was not depauperate when compared with that recorded in similar studies of largely undisturbed catchments.
4. Although the site-groups could be divided into those from the rhithron (groups A-D) and those from the potamon (group E), further longitudinal zonation was not observed. Families of macroinvertebrates were not generally confined to one or other of the two zones.
5. The abundance of shredders and scrapers decreased markedly in the lowland sites while the abudance of filterers increased. These changes are generally the same as predicted by previous studies.

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Appendix. 1. The range of current velocities (m s^{-1}) measured above each sampling position, for each site for each sampling date. Velocities are the average of two measurements (at 0.2 and 0.8 depth) and, where appropriate, different habitats or substrata are indicated. c, cobble;r, riffle; s, sand; p, pool.

Site	May 1979	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980
1	0.27-0.58	0.20-0.47	0.12-0.57	0.15-0.31	0.21-0.39	0.24-0.56
4	0.13-0.28	0.18-0.54	0.19-0.56	0.10-0.44	0.15-0.46	0.07-0.43
5	0.10-0.44	0.13-0.52	0.29-0.44	0.31-0.47	0.27-0.56	0.26-0.50
6	0.38-0.92	0.41-0.73	0.38-1.02	0.22-0.70	0.17-0.66	0.45-0.87
12	0.36-1.15	0.42-1.28	0.66-2.70	0.13-0.74	0.13-0.87	0.45-0.81
15	0.13-0.65	0.44-1.14	0.27-0.76	0.11-0.68	0.13-0.66	0.17-0.51
28 c,r	0.33-0.82	0.36-0.74	0.48-0.60	0.56-0.74	0.38-0.76	0.33-0.59
28 s	0.11-0.31	0.05-0.27	0.19-0.30	0.15-0.28	0.09-0.30	0.07-0.28
33	0.23-1.02	0.27-0.97	0.36-0.84	0.33-0.86	0.26-0.79	0.30-1.16
35	0.18-0.64	0.17-0.36	0.11-0.42	0.23-0.87	0.08-0.80	0.24-0.71
39	0.19-0.44	0.07-0.31	0.11-0.33	0.17-0.38	0.07-0.40	0.07-0.48
41 r	0.39-0.61	0.38-0.74	0.23-0.43	0.12-0.47	0.27-0.48	0.58-0.94
41 p	0.04-0.23	0.09-0.21	0.12-0.20	0.06-0.18	0.06-0.23	0.04-0.14
43	0.17-0.26	0.08-0.52	0.20-0.31	0.04-0.20	0.22-0.46	0.09-0.49
52	0.17-0.80	0.19-0.78	0.43-1.04	0.09-0.87	0.16-0.73	0.17-0.87
53 c,r	0.23-0.66	0.46-1.14	0.60-1.10	0.32-0.80	0.34-0.72	0.22-0.94
53 s	0.14-0.26	0.23-0.44	0.27-0.45	0.16-0.31	0.22-0.32	0.14-0.26
55	0.09-0.35	0.09-0.33	0.22-0.39	0.19-0.35	0.05-0.27	0.19-0.35
57 r	0.29-0.79	0.30-0.84	0.78-1.74	0.44-1.08	0.58-1.08	0.60-1.24
53 p	0.09-0.24	0.07-0.22	0.20-0.34	0.04-0.08	0.05-0.10	0.24-0.31
60 r	0.12-0.24	0.21-0.36	0.38-0.60	0.20-0.73	0.29-0.48	0.22-0.34
60 p	0.07-0.13	0.09-0.11	0.04-0.27	0.05-0.13	0.04-0.08	0.07-0.13

Appendix. 2. Discharge (m^3s^{-1}) calculated from velocity and depth profiles at each site.

Site	May 1979	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980
1	0.2265	0.1494	0.1496	0.0856	0.0799	0.1716
4	0.2778	0.3686	0.5269	0.1755	0.2453	0.5088
5	1.0809	1.0260	1.1369	0.7938	1.1088	1.2420
6	0.2226	0.2030	0.2339	0.0989	0.1148	0.1853
12	0.3773	0.2724	0.4896	0.1494	0.1106	0.4477
15	2.3325	8.9376	2.4760	1.9170	3.1016	4.1363
28	0.4529	0.4834	0.7973	0.5900	0.3458	0.7488
33	0.9002	1.2744	1.6672	0.8526	0.6235	1.5745
35	2.5253	2.2518	3.0975	2.0811	1.8903	3.6200
39	0.1881	0.1539	0.1930	0.0930	0.1187	0.1148
41	0.1184	0.1749	0.4749	0.0807	0.0965	0.1276
43	1.0114	1.0624	1.4427	0.3816	0.7463	0.8913
52	0.9913	0.8379	2.1216	0.6715	0.8372	0.9594
53	0.1910	0.3643	0.4255	0.1798	0.1560	0.2097
55	2.1525	1.2534	2.6730	1.8049	0.7612	2.0952
57	0.1376	0.1360	0.7472	0.0969	0.1218	0.7640
60	0.0587	0.0419	0.1672	0.0570	0.0256	0.0540

Appendix. 3. Percentage contribution (by weight) of each size class of sediment averaged over ten samples for each cobble site. Mixed sites (nos. 28, 35 and 53) are averaged over five samples.

Size class	Site										
	6	12	15	28	33	35	41	52	53	57	60
May 1979											
›64	61.37	37.46	43.90	12.86	32.60	-	21.23	57.56	32.68	16.01	22.45
64-32	28.19	42.36	38.29	29.74	40.17	27.88	44.92	31.33	38.12	37.78	37.35
32-16	7.35	15.51	11.55	15.60	15.67	46.81	18.15	9.12	21.06	20.45	22.59
16-8	1.94	4.04	3.77	40.08	8.34	21.60	8.53	1.56	6.74	13.54	9.16
8-4	1.12	0.57	2.34	1.37	2.44	3.24	4.69	0.38	1.29	7.06	3.70
4-2	0.06	0.06	0.12	0.35	0.78	0.48	2.48	0.06	0.11	5.16	4.74
mean particle size	54.87	48.55	49.84	31.15	45.07	27.41	40.88	54.28	45.15	35.49	39.18
August 1979											
›64	49.93	42.67	61.29	39.71	53.19	-	34.64	51.52	26.00	9.57	23.07
64-32	33.52	36.20	31.11	32.16	30.32	21.52	34.76	37.77	39.18	44.87	44.10
32-16	11.52	16.22	5.75	20.01	10.67	50.93	17.59	8.69	23.36	24.84	23.31
16-8	3.14	3.64	1.38	5.64	4.35	21.71	9.2	1.79	8.15	13.90	6.96
8-4	1.71	9.94	0.45	1.86	1.41	4.54	3.46	0.17	3.07	6.04	2.42
4-2	0.17	2.68	0.02	0.62	0.06	1.30	0.36	0.05	0.25	0.78	0.13
mean particle size	51.29	49.69	55.73	46.46	51.76	25.46	44.39	53.41	42.22	35.67	42.51
October 1979											
›64	53.64	42.29	55.11	14.94	51.21	-	42.26	60.18	28.39	10.53	35.87
64-32	35.47	43.07	38.69	44.67	31.42	-	32.55	28.79	43.24	44.37	32.34
32-16	7.74	12.78	4.45	23.84	10.77	-	17.13	9.28	23.55	26.87	17.71
16-8	1.45	1.75	1.25	9.64	5.18	-	5.71	1.56	4.43	11.67	9.83
8-4	1.47	0.06	0.45	4.25	1.29	-	2.16	0.10	0.22	4.87	3.78
4-2	0.21	0.04	0.05	2.66	0.12	-	0.19	0.10	0.16	1.69	0.47
mean particle size	53.48	51.02	55.08	38.21	51.14	-	47.60	54.75	45.12	36.22	44.15
February 1980											
›64	52.37	46.79	57.25	31.95	28.30	-	34.86	50.20	18.36	7.81	41.63
64-32	34.61	38.01	32.73	25.47	46.30	8.07	40.02	37.36	39.42	54.47	26.60
32-16	9.31	11.92	7.75	24.44	16.53	54.55	14.50	9.40	26.00	23.57	18.90
16-8	1.88	2.75	1.44	13.63	6.49	31.48	7.22	2.40	9.73	9.77	7.96
8-4	1.61	0.39	0.80	3.95	1.64	5.46	3.25	0.53	5.10	4.12	4.02
4-2	0.21	0.13	0.03	0.56*	0.09	0.45	0.14	0.07	1.38	0.26	0.89
mean particle size	52.69	51.40	54.43	40.42	45.18	21.08	46.06	52.63	38.42	38.22	45.17
May 1980											
›64	46.70	36.72	52.17	36.79	50.88	-	35.43	53.94	25.45	3.31	29.83
64-32	35.81	48.89	31.87	35.55	28.52	16.77	42.92	36.57	44.54	44.44	34.91
32-16	13.32	12.22	9.06	19.20	12.76	53.54	14.41	7.54	20.68	29.27	21.51
32-16	2.89	1.99	3.96	5.99	5.51	24.62	5.27	1.58	6.90	14.76	9.45
8-4	1.02	0.16	1.99	2.14	1.41	4.30	1.69	0.24	1.87	6.06	3.55
4-2	0.26	0.02	0.95	0.33	0.92	0.76	0.26	0.12	0.56	2.15	0.75
mean particle size	50.68	50.14	51.48	46.07	50.08	24.13	47.47	54.09	43.58	32.67	42.37
November 1980											
›64	52.33	30.36	58.08	29.57	66.34	-	40.33	57.15	30.01	9.34	20.06
64-32	35.27	49.17	32.79	39.56	24.31	22.70	39.97	30.42	42.84	54.89	41.43
32-16	10.68	19.97	6.30	18.38	6.27	55.10	13.58	8.78	18.91	19.45	22.41
16-8	1.36	5.06	2.26	7.16	2.10	19.09	4.74	2.49	6.94	9.67	10.81
8-4	0.24	0.33	0.44	2.94	0.41	2.61	1.14	0.78	1.22	4.66	4.05
4-2	0.13	0.17	0.13	2.36	0.06	0.50	0.24	0.37	0.08	2.00	1.24
mean particle size	53.16	48.45	54.72	43.43	55.90	26.58	48.90	53.64	45.21	32.51	39.68

Appendix. 4. Mean weight (g) of organic matter per sample. Where appropriate, different substrata or habitats are indicated. c, cobble, r, riffle, s, sand, p, pool.

Site	Aug 1979	May 1980	Nov 1980	mean	Site	Aug 1979	May 1980	Nov 1980	mean
1	0.559	2.743	1.448	1.583	41 r	0.329	2.777	0.488	1.132
4	0.274	3.129	0.616	1.340	41 p	0.329	1.598	0.681	0.869
5	1.209	1.116	1.580	1.302	43	0.466	2.272	1.585	1.434
6	0.084	1.308	0.866	0.753	52	0.138	0.532	0.949	0.540
12	0.461	1.856	1.462	1.260	53 c, r	0.137	0.123	1.679	0.980
15	0.095	0.870	0.678	0.548	53 s	0.122	0.816	1.630	0.856
28 c,r	0.158	3.498	1.952	1.869	55	0.080	4.032	1.035	1.716
28 s	0.006	0.893	0.759	0.573	57 r	0.055	1.874	1.114	1.014
33	0.088	0.463	1.574	0.708	57 p	0.049	1.539	0.537	0.708
35	0.114	0.988	0.722	0.608	60 r	0.084	1.751	1.143	0.993
39	2.106	2.064	1.528	1.899	60 p	0.193	0.869	1.178	0.746

Appendix. 5. A systematic list of the taxa and their total abundances at each site. The nomenclature is that established for the voucher system of the Biological Survey Department, Museum of Victoria. The asterisk (*) indicates taxa collected from log brush samples. A = adults.

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
TRICLADIDA																	
Dugesiidae unidentified	-	10	10	-	10	-	-	10	-	-	10	10	-	-	-	30	-
NEMATOMORPHA																	
Gordiidae																	
*<u>Gordius</u>	10	-	-	11	-	-	-	11	-	-	-	-	-	-	-	-	1
OLIGOCHAETA																	
Oligochaeta spp.	1511	2171	3658	2390	1653	3841	1046	6070	11320	1740	4640	3675	1460	4055	1275	16492	5145
BIVALVIA																	
Corbiculidae																	
*<u>Corbiculina australis</u>	44	95	57	-	11	20	-	-	10	15	50	100	-	32	60	175	-
Bivalvia unidentified	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	10	-
GASTROPODA																	
Ancylidae																	
<u>Ferrissia tasmanica</u>	10	10	-	10	-	-	-	10	1	-	-	-	-	-	5	10	40
<u>Ferrissia</u> immature	-	-	-	-	-	10	-	10	20	-	-	-	-	-	-	-	-
<u>Ferrissia</u>																	
Hydrobiidae																	
*<u>Potomopyrgus niger</u> (Quoy & Gaimard)	25	-	107	50	10	-	-	10	-	760	1055	20	-	20	-	-	2880
<u>Glacidorbus hedleyi</u> Iredale	-	-	30	-	-	-	-	-	36	-	-	-	-	15	-	-	-
Lymnaeidae																	
<u>Austropeplea tomentosa</u> (Pfeiffer)	10	-	-	60	10	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda unidentified	20	10	25	30	5	10	-	-	-	445	120	10	-	15	10	10	80
HYDRACARINA																	
Hydracarina unidentified	55	116	161	160	704	540	80	380	61	80	175	110	120	605	70	1075	640
AMPHIPODA																	
Eusiridae																	
*<u>Pseudomoera gabrieli</u> (Sayce)	15	112	-	52	34	20	10	-	-	477	20	-	-	-	-	-	260
*<u>Paramoera fontana</u> (Sayce)	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-
Ceinidae																	
<u>Austrochiltonia australis</u> (Sayce)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Gammaridae																	
<u>Perthia</u> sp. 1	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*Gammaridae unidentified	-	-	10	-	-	-	-	-	-	-	-	35	-	-	-	-	-
DECAPODA																	
Atyidae																	
<u>Paratya australiensis</u> (Kemp)	-	-	-	-	-	-	-	-	11	-	11	-	-	-	-	20	-
ISOPODA																	
Janiridae																	
<u>Heterias</u> sp. 1	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-

Appendix 5 (continued).

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43′	52	53	55	57	60
EPHEMEROPTERA																	
Oligoneuriidae																	
*Coloburiscoides spp.	10	-	20	93	1	7	30	34	14	-	-	40	52	43	-	-	-
Siphlonuridae																	
Tasmanophlebia lacus coerulei Tillyard coerulei	-	20	-	-	-	-	11	180	-	-	-	-	-	12	-	-	2
Ameletoides lacus albinae Tillyard albinae	-	-	-	-	-	-	85	-	-	-	-	-	-	-	-	-	-
Leptophlebiidae																	
*Atalophlebioides sp. 1	35	-	81	1435	2070	3485	636	2184	431	-	50	50	2718	1897	50	163	738
*A. pusillum (Harker)	-	-	-	-	-	1230	-	30	129	25	3687	250	15	10	-	83	1755
sp 4	-	-	63	-	-	-	-	-	90	-	-	-	-	-	5	-	-
*Atalonella sp. 1	20	11	45	16	1	-	30	-	-	15	-	-	10	10	5	20	-
* sp. 2	95	43	235	182	191	75	30	41	379	96	845	220	70	40	40	215	101
sp. 3	35	-	25	-	1	-	-	-	-	-	230	60	-	-	5	-	91
* sp. 4	40	-	35	-	-	65	-	-	55	25	10	10	90	-	90	-	10
*Atalophlebia (nr.) longicaudata (sp. 1)	-	-	-	10	-	-	-	40	15	-	-	-	-	-	-	-	-
sp. 2	-	-	-	120	-	-	-	-	-	-	-	-	-	-	-	-	-
*A. australis (Walker)	-	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	-
sp. 4	-	-	-	-	-	-	-	10	60	-	-	10	-	-	-	-	-
sp. 6	-	-	-	-	10	-	-	70	11	-	90	-	-	-	-	-	11
sp. 9	-	-	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-
Jappa sp. 1	-	-	-	-	-	51	-	10	-	5	10	-	-	-	-	-	50
sp. 2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-
sp. 3	-	-	5	-	-	120	-	-	2	-	260	20	10	-	-	-	35
Kirrara procera Harker	-	-	-	-	-	30	5	20	-	-	-	-	-	-	-	-	-
*Leptophlebiidae immature	130	357	433	364	1367	2270	216	1440	307	595	2365	650	3270	1625	170	431	3370
Caenidae																	
Tasmanocoenis tonnoiri Lestage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	398	-
* sp. 2	45	20	-	-	45	2270	5	1860	1	25	1175	20	50	30	285	10	580
Baetidae																	
*Baetis sp. 1	200	331	42	683	-	-	772	-	-	-	125	-	140	-	10	-	-
* sp. 2	-	-	-	-	120	-	-	10	-	-	10	80	27	81	-	-	-
* sp. 3	60	-	20	18	146	1897	200	532	20	5	540	5	434	30	-	55	632
* sp. 4	10	-	-	-	-	-	-	90	135	-	50	65	-	-	235	60	80
* sp. 5	50	95	60	120	-	20	-	90	21	-	255	101	40	-	-	55	10
* sp. 6	-	-	-	-	-	50	-	-	411	-	-	64	-	10	5	30	-
Centroptilum sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	60
*Baetidae immature	-	55	31	30	105	250	415	250	150	20	410	110	90	65	25	131	390
ODONATA																	
Aeshnidae																	
Austroaeshna sp. 2	-	-	-	-	-	-	-	10	-	-	-	-	-	1	-	-	10
* sp. 3	-	15	-	-	-	1	-	10	-	-	10	-	-	-	-	-	12
Notaeschna sagittata (Martin)	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	20
Aeshnidae immature	10	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gomphidae sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	102	-
*Gomphidae immature	-	-	-	-	10	-	-	-	-	-	-	-	-	-	10	-	-
Synthemidae sp. 1	-	1	-	-	-	1	-	2	-	-	-	-	-	-	21	-	-
PLECOPTERA																	
Eustheniidae																	
Stenoperla australis Tillyard	20	48	35	60	125	43	70	271	20	-	26	-	172	43	-	-	10

Appendix 5 (continued).

	site numbers															
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
**Eusthenia venosa* (Tillyard)	-	15	-	10	31	-	55	-	-	-	-	-	-	-	-	-	-
Notonemouridae																	
**Austrocercella marianna*e Illies	60	198	10	50	71	-	400	-	-	60	355	-	185	-	-	10	960
*Notonemouridae unidentified	25	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Austroperlidae																	
**Acruroperla atra* Samal	-	10	-	-	22	-	10	10	-	-	-	-	68	61	35	-	10
**Austropentura victoria* Illies	235	20	142	10	225	-	80	30	-	-	-	-	156	10	-	-	11
**Austroheptura picta* (Riek)	5	10	262	-	4	1	-	-	-	-	-	-	142	25	10	-	-
Austroperlidae immature	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gripopterygidae																	
Eunotoperla kershawi Tillyard	-	-	-	1	-	-	2	10	-	-	-	-	-	-	-	-	-
**Illiesoperla australis* Tillyard	1	-	-	6	144	-	11	121	-	10	10	15	91	-	-	51	41
**Trinotoperla irrorata* Tillyard	-	-	-	10	10	-	10	10	-	-	-	-	10	20	-	-	-
**T. nivata* Kimmins	6	-	-	-	-	10	-	30	-	-	-	1	198	2	-	-	-
T. yeoi Perkins	10	10	10	1	23	10	-	10	-	-	5	-	20	-	-	-	10
Trinotoperla immature	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-
**Neboissoperla alpina* McLellan	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
**Newmanoperla thoreyi* McLellan	-	-	-	-	-	-	-	110	-	20	-	-	-	-	-	15	-
Leptoperla neboissi McLellan	-	-	-	-	-	-	-	-	5	-	-	10	-	-	10	-	-
**L. primitiva* McLellan	-	-	-	20	-	-	-	20	10	-	-	-	-	1	-	-	-
**L. kimminsi* McLellan	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-
**L. bifida* McLellan	-	-	-	-	-	-	-	-	-	-	-	-	-	10	5	-	-
**Riekoperla tuberculata* McLellan	5	20	-	105	47	60	50	20	30	-	-	15	62	20	11	30	-
**R. rugosa* (Kimmins)	-	68	5	25	40	90	245	230	-	20	115	-	270	70	35	10	160
**R. karki-reticulata* group	5	189	22	150	212	-	530	10	5	-	-	-	50	10	20	-	30
Dinotoperla christinae McLellan	-	-	-	30	10	-	20	-	5	-	-	5	-	-	-	-	-
**D. arenaria* Hynes	-	-	5	115	140	20	10	20	-	-	-	-	174	10	-	-	-
**D. fontana* Kimmins	-	15	-	-	-	190	-	192	-	10	10	-	121	51	10	-	20
**D. serricauda* Kimmins	10	20	-	50	50	30	-	-	-	-	10	-	-	-	-	45	-
**D. serricauda* / **D. brevipennis* Kimmins	-	-	-	10	-	10	-	10	-	-	10	30	10	-	10	-	-
*Gripopterygidae immature	43	59	9	-	98	30	585	40	10	10	20	-	30	30	30	10	100
*Plecoptera immature	6	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-
HEMIPTERA																	
Corixidae immature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	10
MEGALOPTERA																	
Corydalidae																	
Archichauliodes sp. 1	-	-	-	-	43	2	10	20	-	-	41	-	150	10	-	82	-
sp. 2	10	10	-	-	-	-	-	-	5	-	21	-	-	-	-	50	-
NEUROPTERA																	
Neurorthidae																	
Austroneurorthus sp. 1	24	2	15	32	52	-	-	-	-	-	-	-	61	53	-	-	30
sp. 2	-	-	-	-	-	-	-	-	-	-	110	-	-	-	-	-	-

Appendix 5 (continued).

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
sp. L58E	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-
sp. L63E	-	-	-	-	-	-	10	200	-	-	10	-	-	-	-	-	-
sp. L64E	15	3	-	-	-	-	-	-	-	30	-	-	-	-	-	10	-
sp. L65E	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Austrolimnius immature	5	540	130	340	390	305	30	730	565	385	20	50	-	550	125	-	60
Genus A sp. L15E	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-
Elmidae immature	145	197	10	-	21	-	-	-	-	-	-	-	-	-	-	-	-
*Kingolus yarrensis (A)	-	-	-	30	-	-	50	-	-	-	-	-	-	-	-	-	-
*Kingolus unidentified (A)	-	-	-	-	-	20	5	10	-	-	10	-	-	-	-	-	20
*Simsonia hopsoni (A)	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-
Simsonia sp. 1 (A)	-	-	-	-	-	-	80	-	-	-	-	-	-	-	-	-	-
*Simsonia unidentified	-	-	-	10	-	-	10	-	-	-	-	5	-	-	-	-	-
*Notriolus quadraplagiatus (A)	-	-	-	-	-	-	-	-	15	-	-	10	-	-	-	-	-
*Notriolus unidentified (A)	-	10	-	-	-	-	-	20	-	10	10	15	-	20	-	-	-
*Austrolimnius sp. 2 (A)	25	-	10	65	165	-	10	20	-	-	40	-	60	120	-	20	-
* sp. 3 (A)	-	-	-	-	-	10	-	-	-	85	325	-	-	-	-	10	40
sp. 5 (A)	-	30	10	-	-	-	-	10	-	-	-	-	-	-	-	-	-
sp. 6 (A)	-	-	-	-	-	-	-	10	-	-	-	-	-	-	5	-	-
*Austrolimnius unidentified (A)	50	1073	52	580	954	505	395	1040	152	115	265	40	560	615	490	5	140
DIPTERA																	
*Tipulidae sp. 1	364	296	218	111	50	120	167	134	91	597	134	141	91	294	249	75	201
sp. 2	-	-	-	-	-	40	-	-	-	-	-	-	10	-	-	-	-
sp. 3	31	97	60	11	30	20	61	40	62	55	10	-	103	70	56	127	20
sp. 5	-	-	-	-	10	-	-	-	5	-	-	-	-	-	-	-	-
* sp. 10	24	56	10	60	45	72	62	72	25	148	0	30	32	80	0	10	12
* sp. 17	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-
* sp. 17	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-
* sp. 20	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-
Clytocosmus edwardsi Alex.	-	-	-	18	25	-	-	-	-	-	-	-	-	-	-	-	-
Tipulidae sp. 24	-	5	9	5	1	-	-	1	25	25	36	5	-	30	6	-	20
sp. 28	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-
sp. 29	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-
sp. 30	-	-	-	-	-	-	-	70	-	-	-	-	10	-	-	-	1
sp. 31	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-
sp. 32	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-
sp. 34	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-
* sp. 35	48	35	12	96	81	-	61	-	-	-	-	-	10	42	-	-	-
sp. 47	15	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	10
sp. 51	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tipulidae immature	-	10	10	-	-	-	15	10	30	45	-	-	10	-	-	-	20
Tipulidae pupae	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-
Tanyderidae sp. 1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*Psychodidae sp. 1	-	-	-	20	-	-	-	20	-	-	-	-	-	-	-	-	-
Dixidae sp. 1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	10
* sp. 2	-	-	-	90	11	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae (Orthocladiinae)																	
*Rheocricotopus sp. 1	-	-	-	10	-	10	-	-	-	-	-	-	-	-	10	-	-
*nr. Eukiefferiella sp. 1	-	-	-	370	214	110	210	300	-	-	135	40	545	100	10	150	360
*?Eukiefferella sp. 1	-	127	158	95	59	290	290	140	360	40	670	220	240	365	80	1230	3175
Eukiefferella																	
*Thienemaniella sp. 1	35	86	38	45	42	515	30	250	781	170	280	100	250	15	60	220	1355
*Cricotopus sp. 1	50	803	37	105	61	940	115	310	569	565	2415	470	220	110	120	1902	6685

Appendix 5 (continued).

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
MECOPTERA																	
Nannochoristidae																	
Nannochorista sp. 1	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	30
COLEOPTERA																	
Dytiscidae																	
Sternopriscus sp. 1	42	107	23	10	-	-	-	11	-	-	-	-	-	25	20	-	-
Gryinidae																	
Macrogyrus oblongus apacior Blackburn (A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
M. oblongus apacior	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	20
Hydraenidae sp. 1	-	-	-	-	-	10	-	-	-	-	30	-	-	10	-	-	10
Hydrochidae																	
Hydrochus victoriae Blackburn (A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Hydrochus sp. A (A)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Hydrophilidae																	
*Nothydrus australis Blackburn (A)	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	10
Berosus nr. flindersi Blackburn (A)	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-
*Berosus immature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-
Helodidae																	
*Cyphon sp. 1	997	187	535	395	545	60	275	320	70	110	160	10	201	543	300	10	410
* sp. 5	-	30	28	20	95	30	-	140	-	35	-	10	70	60	5	-	90
Helodidae immature	385	95	100	205	70	-	-	-	-	-	-	-	-	155	5	-	150
Psephenidae																	
*Sclerocyphon maculatus Blackburn	1	2	11	271	85	42	7	10	-	10	65	-	58	148	-	-	358
*S. striatus Lea	-	5	-	-	-	63	-	24	-	-	51	-	-	20	-	3	48
*S. basicollis Lea	-	-	-	40	-	1	-	-	-	-	-	-	-	-	-	-	51
Sclerocyphon sp. A	-	-	-	-	-	11	-	1	-	-	10	-	-	-	-	-	10
Psephenidae immature	-	5	10	40	-	10	5	-	-	13	20	-	10	45	-	-	243
Philodactylidae																	
*Bryrrocryptus sp. 1	8	55	-	186	302	2	-	127	-	185	23	-	25	175	2	-	26
Elmidae																	
*Kingolus sp. L1E	-	-	-	-	-	-	-	-	-	-	10	-	-	10	-	-	25
* sp. L5E	-	1	-	-	-	-	-	-	-	-	-	-	30	50	-	10	-
sp. L7E	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-
* sp. L38E	-	10	-	25	-	-	65	-	-	-	-	-	-	30	-	-	-
* sp. L68E	-	-	-	10	-	20	-	20	-	-	10	10	10	-	-	-	-
Kingolus immature	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-
*Simsonia sp. L2E	10	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
sp. L3E	-	-	-	90	20	50	-	970	-	-	-	10	70	15	-	-	40
S. hopsoni Cart. & Zeck	-	-	1	-	-	-	10	-	-	-	70	-	-	-	-	-	10
*S. tasmanica Blackburn	-	50	-	5	-	10	-	10	-	-	-	-	-	-	-	-	-
* sp. L48E	-	-	-	135	-	-	-	-	1	-	-	25	-	10	-	-	-
*Notriolus quadraplagiatus Cart.	-	-	-	-	13	-	-	-	10	10	-	-	-	-	-	-	-
*N. victoriae Cart. & Zeck	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-
*Notriolus immature	10	-	-	-	-	20	-	20	10	25	70	100	-	20	15	65	30
*Austrolimnius sp. L10E	235	3539	423	3045	1742	2390	975	5250	2076	2245	2230	420	2490	2175	1695	375	1480
* sp. L13E	40	100	407	70	245	-	20	390	-	-	375	-	400	305	15	90	20
* sp. L25E	-	-	-	-	-	-	-	-	32	10	20	-	-	-	10	30	-
A. waterhousei Hinton	-	-	-	-	-	-	-	10	7	-	20	50	-	-	-	60	-
sp. L35E	10	50	-	-	40	-	-	10	-	-	160	-	-	-	-	-	-
sp. L36E	15	2	-	-	-	-	20	-	-	-	20	-	-	-	-	-	-
sp. L39E	-	-	-	-	10	-	10	60	-	-	-	-	-	-	-	25	-

Appendix 5 (continued).

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
*Cricotopus sp. 3	10	-	-	10	-	-	-	-	-	-	10	-	-	-	-	-	-
Corynoneura sp. 1	-	-	-	-	-	170	-	310	30	-	-	-	-	20	1105	10	10
sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	410
Symbiocladius																	
aurifodinae Hynes	-	-	-	-	-	20	-	-	-	-	-	-	20	10	-	-	20
*nr. Eurycnemus sp. 1	-	-	-	-	-	-	5	10	-	-	-	-	-	-	-	-	-
*?nr. Eurycnemus sp. 2	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-
*nr. Cordites sp. 1	1086	1411	743	11C	927	350	845	1330	2473	1935	420	470	2280	1890	1770	1227	20
nr. Cardiocladius sp. 1	-	-	10	-	-	-	-	-	104	-	10	-	30	-	-	10	-
Orthocladiinae sp. 103E	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	250
sp. 113E	-	-	-	-	-	-	-	-	-	-	-	-	20	25	-	-	-
* sp. 117E	5	56	-	50	168	100	165	20	-	-	-	-	-	10	15	-	-
* sp. 124E	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	440	-
(Chironomini)																	
Dicrotendipes sp. 1	-	-	-	-	-	-	40	-	-	-	60	-	-	10	-	-	-
sp. 2	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-
*Riethia sp. 1	95	267	2163	115	186	4915	520	890	286	60	320	35	290	375	860	1475	370
*Cryptochironomus																	
griesiedorsum (Kieffer)	-	-	-	-	-	-	10	-	-	80	-	40	-	-	-	-	20
nr. Saetheria sp. 1	-	-	20	-	-	30	10	20	67	10	10	-	10	20	-	20	-
*Polypedilum sp. 1	25	117	660	30	26	650	145	180	49	120	500	4465	150	160	55	1625	4225
* sp. 7	-	-	-	-	10	-	-	-	-	-	-	-	10	20	-	-	-
*Harnischia gp sp. 1	-	-	10	-	-	100	30	20	10	-	10	-	10	40	-	-	-
* sp. 2	-	-	8	-	10	-	10	-	22	40	-	150	-	30	-	10	30
*Skusella sp. 1	-	-	60	10	30	730	-	180	-	-	-	-	1855	1835	25	-	710
Parachironomus sp. 1	10	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-
?Parachironomus sp. 2	-	-	-	-	-	-	-	-	117	-	-	-	-	-	-	-	-
*?Parachironomus sp. 3	-	7	31	-	-	80	-	150	446	170	-	25	50	115	895	678	10
Paraborniella sp. 1	-	-	-	-	-	-	10	-	3	60	-	20	-	-	-	-	-
*Chironomini sp. 3E	5	10	10	10	-	10	5	40	-	10	-	-	-	5	-	10	-
sp. 34E	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(Tanytarsini)																	
*Rheotanytarsus sp. 1	10	174	20	175	63	2005	195	940	530	110	3385	105	170	340	240	3550	7390
*?Calopsectra sp. 1	290	247	207	60	395	1170	-	120	429	1775	1680	8155	170	705	200	1750	860
*Micropsectra sp. 1	-	-	-	10	10	20	20	20	10	-	160	100	20	-	5	452	700
sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60
*Stempellina nr. bausei																	
sp. 1	10	-	-	90	20	170	-	30	-	30	80	-	10	55	30	10	1650
Tanytarsini sp. 122E	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	10	-
(Tanypodinae)																	
*Ablabesmyia sp. 1	20	10	25	-	50	100	10	170	40	135	40	-	30	70	50	100	30
*Macropelopia sp. 1	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-
*Pentaneura sp. 1	30	124	342	85	145	215	170	130	124	475	285	1090	220	205	105	171	1220
*Procladius sp. 1	15	-	-	-	-	120	35	30	30	95	240	40	-	155	10	210	630
Coelopynia pruinosa																	
Freeman	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-
Tanypodinae sp. 108E	50	-	60	-	-	20	-	90	21	-	-	20	20	-	-	25	-
sp. LTCS15	-	-	-	-	-	10	-	-	-	-	10	-	-	-	-	10	-
Aphroteniinae sp. 18E	15	50	20	10	-	120	-	690	20	-	-	-	180	55	10	100	-
(Podonominae)																	
Podonomopsis sp. 1	-	41	-	155	177	20	605	710	1	-	180	5	1065	175	45	-	210
*Podonomus sp. 1	20	91	2	60	81	40	245	140	291	40	20	-	225	255	140	-	10
Chironomidae pupae	45	51	35	25	127	120	40	60	84	30	290	40	110	60	60	245	255
*Chironomidae immature	40	171	198	116	114	730	205	200	229	75	260	265	355	180	160	880	3925
Ceratopogonidae																	
Dasyhelea sp. 1	-	-	-	10	-	-	-	-	60	5	-	-	10	-	55	-	-
sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-
Nilobezzia sp. 1	15	36	2	40	66	90	80	170	-	55	650	-	120	45	15	25	345
Alludomyia sp. 1	10	-	-	60	5	10	-	-	-	-	-	-	-	20	-	-	10

Appendix 5 (continued).

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
Bezzia sp. 1	-	10	-	-	-	-	-	50	-	5	50	-	-	-	-	-	470
nr. Leptoconops sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	10	-
Monohelea sp.	-	-	-	30	-	-	-	-	-	10	20	-	-	10	-	-	120
*Ceratopogonidae sp. 7	-	12	-	35	30	-	-	-	-	-	-	-	10	10	-	120	180
sp. 13	-	-	-	-	-	-	10	-	-	-	220	-	-	-	-	-	-
immature	-	-	-	-	-	-	10	10	10	-	-	20	-	10	-	-	50
Simuliidae																	
*Austrosimulium montanum																	
Mackerras & Mackerras	60	-	1	-	-	-	10	-	-	-	-	-	-	25	-	-	-
*A. victoriae Rouband	-	20	-	90	70	820	10	1091	11	-	740	30	60	170	25	-	2110
*A. furiosum Skuse	25	-	5	30	82	1390	35	1650	40	40	870	80	20	110	45	210	1580
Simulium ornatipes Skuse	-	-	-	-	-	10	-	-	25	-	-	-	-	-	-	80	-
*Cnephia aurantiacum																	
Tonnoir	20	-	15	50	3	-	-	-	-	-	-	-	-	360	-	70	-
Simuliidae pupae	-	-	-	-	-	20	-	20	-	-	10	-	-	-	5	-	-
Simuliidae immature	40	-	-	205	100	1050	-	1950	10	-	830	165	90	355	5	720	2730
Blephariceridae																	
Edwardsina alticola																	
Zwick	-	-	-	50	5	10	-	20	-	-	-	-	-	20	-	-	-
E. affinis (Zwick)	-	-	-	-	-	10	-	-	-	-	-	-	10	-	-	-	-
E. polymorpha Zwick	-	30	-	216	81	155	10	651	-	-	-	-	143	113	-	-	-
E. torrentium torrentium																	
Zwick	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-
Apistomyia tonnoiri																	
Tillyard	-	-	-	55	90	10	-	150	-	-	-	-	-	10	-	-	-
Blephariceridae pupae	-	-	-	40	-	31	-	30	-	-	-	-	-	20	-	-	-
Blephariceridae immature	-	1	-	130	30	80	20	150	-	-	-	-	35	50	-	-	-
Athericidae sp. 3	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-
sp. 4	-	29	-	23	21	100	6	94	-	-	-	-	42	31	62	-	30
Athericidae immature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Tabanidae sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
*Empididae sp. 2	-	57	10	115	10	70	85	90	99	55	25	10	40	55	30	10	450
* sp. 3	-	10	-	-	3	-	-	-	189	5	-	165	30	-	50	737	40
sp. 4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
* sp. 5	-	-	-	10	21	40	-	-	-	-	-	-	-	10	-	-	20
sp. 6	-	-	1	-	10	-	-	-	-	-	-	-	-	-	-	-	-
sp. 9	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Empididae pupae	-	10	-	-	-	10	-	-	-	-	-	-	-	-	30	-	10
Sciomyzidae sp. 1	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA																	
Hydrobiosidae																	
*Ethochorema sp. 1	-	1	-	-	56	-	10	-	-	-	21	-	-	-	-	-	-
*Ethochroema gp	-	11	1	146	168	107	40	40	45	25	163	40	290	73	-	30	118
Taschorema rugulum																	
Neboiss	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-
Austrochorema sp. 1	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-
*Apsilochorema obliquum																	
Mosely	5	13	1	40	83	11	-	20	-	-	56	-	112	130	-	-	258
A. gisbum (Mosely)	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
*Psyllobettina locula																	
Neboiss	-	-	-	10	-	-	30	-	-	-	-	-	30	-	-	-	-
*P. nr. cumberlandica	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-
*Ulmerochorema gp.	5	-	-	10	-	10	-	-	-	-	78	-	-	10	10	-	5
Ulmerochorema sp. 2	-	-	-	-	-	10	-	10	-	-	-	-	10	-	-	-	-
*Tanjilana sp. 1	-	-	-	-	100	30	-	-	13	11	-	20	10	-	-	71	40
*Hydrobiosidae sp. 14	-	-	-	-	-	40	-	20	-	-	-	-	-	-	-	-	-
sp. 15	-	-	-	-	-	-	20	-	40	-	-	-	-	-	-	-	-
* immature	-	1	-	90	40	10	10	10	10	10	15	-	35	10	-	41	20

Appendix 5 (continued).

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
Glossosomatidae																	
*Agapetus sp. 1	-	35	1	665	939	280	115	310	-	20	270	10	1737	390	5	5	160
sp. 2	-	-	-	-	-	-	-	-	-	-	10	-	10	-	10	-	-
Hydroptilidae																	
*Hydroptila sp. 1	-	-	-	-	11	-	-	-	-	-	-	-	10	10	-	-	-
* sp. 2	5	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	5
*H. (?scamanda)	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	30	-
*Orthotrichia aberrans gp	-	-	-	-	21	-	1	-	-	-	-	-	10	22	-	-	-
*O. atraseta Wells	-	-	10	30	-	30	-	-	-	-	-	-	10	100	-	10	90
Maydenoptila cuneola Neboiss	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-
Hellyethira (?simplex)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Hellyethira sp. 2	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	10	-
*Oxyethira columba (Neboiss)	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	153	-
Hydroptilidae immature	-	-	-	50	30	70	10	10	20	-	50	-	-	250	10	50	230
Philopotamidae																	
*Hydrobiosella sp. 1	-	-	-	15	2	-	10	60	-	-	-	-	-	13	-	-	-
sp. 2	-	-	-	-	11	-	-	10	5	-	-	-	-	-	-	-	-
*Chimarra sp. 1	-	10	-	10	20	30	-	11	-	-	20	10	10	70	10	10	10
Philopotamidae immature	-	10	-	-	1	10	10	-	-	-	30	-	10	30	10	90	10
Ecnomidae																	
*?Ecnomina sp. 1	-	-	-	-	-	162	-	100	-	-	-	-	10	10	181	5	-
* sp. 2	-	-	-	-	-	-	-	20	20	-	-	-	-	-	-	47	-
sp. 4	-	-	-	-	-	10	-	10	24	-	-	-	-	-	-	10	-
Ecnomus sp. 1	10	-	-	-	-	31	-	-	-	25	851	-	-	-	-	-	763
*Ecnomus spp.	-	-	-	-	-	-	10	10	12	-	80	165	-	10	52	1517	-
Ecnomidae immature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
*Polycentropodidae sp. 4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
* sp. 5	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	10	-
immature	10	-	-	-	-	-	-	10	10	-	20	-	-	10	-	-	220
Hydropsychidae																	
*Austropsyche sp. 1	40	10	21	52	-	30	-	-	10	-	-	10	-	23	-	-	-
*?Smicrophylax sp. 1	-	-	-	-	20	40	145	30	13	-	-	-	100	232	10	220	80
* sp. 2	-	-	-	-	10	10	-	-	-	-	-	-	-	20	-	-	-
*Asmicridea edwardsii (MacLachlan)	-	-	-	10	12	80	-	30	45	-	105	-	185	30	-	1003	101
* sp. 2	-	-	-	-	-	30	-	30	-	-	-	-	-	-	-	-	-
*Cheumatopsyche sp. 1	-	-	-	-	-	10	10	-	15	-	-	-	11	10	-	4768	-
sp. 2	-	-	-	-	10	-	-	-	1	-	-	46	-	-	-	21	-
* sp. 3	-	-	-	-	-	-	-	-	-	1	56	-	-	-	-	-	240
*Hydropsychidae immature	-	10	10	10	20	80	20	10	25	30	10	-	160	10	-	1174	130
Helicopsychidae																	
Helicopsyche sp. 1	-	-	-	-	-	-	-	-	-	-	10	-	30	-	-	-	-
*Allocella grisea Banks	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-
*Helicophidae sp. 2	-	-	-	-	10	-	-	-	-	-	-	-	10	-	-	-	-
* sp. 3	-	-	-	75	150	-	80	-	5	-	-	-	30	10	-	-	30
Conoesucidae																	
*Conoesucus sp. 1	-	-	-	80	-	30	20	-	127	10	130	10	-	10	-	-	570
Conoesucidae sp. 3	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
* sp. 7	-	1	-	-	-	-	-	-	-	-	5	-	25	-	-	-	10
* sp. 9	-	-	20	-	-	10	-	10	-	-	80	20	-	-	10	-	660
* sp. 10	10	5	-	120	14	111	-	50	-	10	-	-	51	30	-	-	-
Costora delora Mosely	-	-	-	-	-	10	-	-	10	-	-	-	-	-	-	-	-
Conoesucidae sp. 13	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	1360
sp. 17	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-
* immature	-	-	-	40	-	30	-	-	25	-	-	-	10	-	-	20	40
Calocidae																	
Coenota plicata Mosely	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-

Appendix 5 (continued).

	site numbers																
	1	4	5	6	12	15	28	33	35	39	41	43	52	53	55	57	60
**Tamasia variegata* Mosely	-	-	-	-	90	200	89	60	-	-	50	-	441	61	5	-	291
Calamoceratidae																	
Anisocentropus sp. 1	-	10	-	-	-	-	-	-	-	-	40	10	-	-	-	-	90
Philorheithridae sp. 1	55	54	29	3	8	1	44	20	-	27	-	-	-	123	110	-	-
* sp. 2	10	-	-	20	62	140	-	30	-	10	20	5	30	-	-	-	60
* sp. 3	-	-	-	-	-	11	10	10	-	-	10	-	-	-	30	-	20
sp. 4	10	-	-	10	-	10	10	-	-	-	-	-	-	-	-	-	-
sp. 6	-	-	1	-	-	1	-	-	10	-	20	10	-	-	-	-	12
sp. 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
sp. 8	5	-	-	-	60	-	-	-	-	5	-	-	-	-	-	-	-
sp. 9	5	5	-	-	-	-	-	10	-	30	20	-	-	10	-	-	2
* sp. 10	-	-	-	10	-	-	-	-	10	-	-	-	5	-	-	-	-
* immature	-	5	10	-	10	10	-	-	-	-	20	-	-	60	-	10	10
Odontoceridae sp. 1	-	-	-	-	-	-	-	10	-	-	50	-	-	-	-	-	-
Leptoceridae																	
**Notalina bifaria* Neboiss	-	-	-	-	-	540	-	80	61	-	210	-	210	30	10	-	2334
**N. fulva* Kimmins (type B)	-	-	-	-	-	40	-	40	-	-	40	5	110	-	10	5	50
Triplectides sp. 2	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-
sp. 3	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-
T. proximus Neboiss	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
Oecetis sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-
sp. 3	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-
Condocerus paludosus Neboiss	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-
*Leptoceridae immature	10	-	15	30	11	2710	15	980	100	5	215	25	1160	90	20	10	1190
Atriplectidae																	
Atriplectes dubia Mosely	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-
Trichopteran pupae	-	-	-	-	10	-	10	-	-	-	-	10	-	-	-	-	-

Appendix 6. List of taxa collected in the November-December 1978 qualitative survey. Also shown are the sites at which they occurred and the percentage frequency with which each taxon was collected in the four types of samples taken, kick samples (KS), log brush samples (BS), sweep samples (SS) and leaf pack samples (LP). For more details of sampling procedures see Suter (1979). At the end of this appendix (p. 60) is a map showing the location of all sites sampled in this survey. See Appendix 5 for family names.

Taxa	Sites at which taxa were collected	KS	BS	SS	LP
Nematomorpha					
Gordius sp	6 12 13 30 52	14	14	42	28
Porifera sp	50 63	50	50		
Bryozoa					
Fredericella ? australiensis	37 65	50	50		
Oligochaeta					
Aelosoma sp 3	17	100			
sp 4	17	100			
Haplotaxis sp 1	30 57 64	100			
Lumbriculus variegatus (Muller)	1 32 34 41 52 57 59 62 63	45	45	10	
Phreodrilus (nr) nothofagi	4		100		
sp 1	6 17	50		50	
sp 2	11 30 37	67		33	
Chaetogaster sp 1	56	100			
Pristina osborni (Walton)	10 31 39 41 62	50	33		17
Nais communis Piguet	4 7 8 14 15 16 17 20 22 27 34 37 41 42 51 54 55 56 57 58 59 63	44	20	36	
Branchiura sowerbyi Beddard	37 61	100			
Talmatodrilus multiprostatus Brinkhurst	7 8 11 12 15 16 17 30 32 35 51 57 60A	62	15	23	
Tubifex tubifex Muller	16 62		100		
Limnodrilus hoffmeisteri Claparede	5 37 59 62 63	40	20	40	
Hirudinea sp	39	100			
Bivalvia					
Hydridella depressa (Lamarck)	43 48	100			
Sphaerium sp	1 4 8 12 62 65	43	14	43	
Gastropoda					
Ferrissiidae sp 1	10 18 19 37		33	67	
Physastra gibbosa (Gould)	16 18 19 37 38 43 45 47 58 62 63 65	7	14	79	
Planorbidae sp 1	11 12			50	50
sp 2	51			100	
Amphipoda					
Pseudomoera ? sp	1 4 5 6 7 8 1 12 14 15 24 26 39 41 60 60A 61	36	32	32	
Austrochiltonia australis	16 17 18 20 22 27 38 45 49 50 51 61 62 65 68	13	6	81	
Niphargus? sp	5 19 20 65		25	75	
Perthia? sp	11 30			50	50
Decapoda					
Paratya australiensis	16 17 18 20 21 22 24 26 27 35 37 38 41 42 43 45 47 49 50 51 57 58 61 62 63 65 66 67	17	3	80	
Euastacus kershawi Smith	5 15 33 43 53 55	100			
Ephemeroptera					
Coloburiscoides sp	1 4 5 6 8 9 10 12 13 14 15 16 17 29 30 31 32 33 34 35 37 53 54 55	35	33	27	5
C. gigantus Tillyard	28 52	50	50		
Tasmanophlebia lacus-coerulei	4 10 11 12 14 16 17 31 32 33 40 41 52 53 54 55 60		6	94	
Ameletoides lacus-albinae	28	50	50		
Atalophlebioides sp 1	6 7 8 9 10 12 13 14 15 17 29 30 31 32 33 34 41 52 53 54 57 60	56	28	16	
sp 2	7 11 60 60A 61	67	33		
A. pusillum	29 42 55	75		25	
sp 4	5 10 14	25	50	25	
sp 5	59	100			

Appendix 6 (continued).

Taxa	Sites at which taxa were collected	KS	BS	SS	LP
Atalonella sp 1	1 4 5 6 7 8 9 10 12 13 14 23 29 30 31	22	39	29	10
	32 34 41 52 53 54 55 57 60A				
sp 2	1 4 5 6 7 8 9 10 11 12 14 15 16 17 24	28	26	36	10
	26 29 30 31 32 34 35 37 40 41 42 52 53				
	54 55 56 57 59 60 60A 61 65				
sp 3	10 12 14 24 31 32 33 52 55 60 60A 61	12	12	47	30
sp 4	16 20 26 27 33 39 40 53 55 58 60	20	40	27	13
Atalophlebia nr longicaudata	4 10 16 17 26 31 35 55	27	55	9	9
sp 2	14 60A 61 65	40		60	
A. australis	16 18 24 26 30 31 38 41 67	22	11	44	22
sp 4	17 18 19			100	
sp 5	19 26		50	50	
sp 6	9	100			
Jappa sp 1	5 9 11 14 20 24 31 33 41 54 55 57	27		45	27
sp 2	57	100			
Kirrara procera	15 34	100			
Tasmanocoenis tonnoiri	58 63 66	38	24	38	
sp 2	10 14 15 16 31 32 33 37 45 51 54 55	45	23	27	5
Baetis sp 1	1 4 5 6 7 8 10 12 13 14 15 29 30	23	41	36	
	31 32 52 53 54 55				
sp 2	5 8 9 10 12 14 32 52	23	54	23	
sp 3	10 12 13 15 16 17 29 31 34 41 42 52	48	42	10	
	54 55 60 60A				
sp 4	14 15 16 17 29 31 33 34 35 38 55 57 66	35	12	53	
sp 5	17 18 19 20 21 22 24 26 37 38 40 42 43	16	6	78	
	47 49 51 57 58 59 61 63 65				
sp 6	17 26 35 40 42 43 50 51 56 58 59 61 63	21	29	50	
	65 66 67				
Cloeon sp 1	47			00	
Centroptilum sp 1	31 53 55 57		100		
Odonata					
Austroaeschna sp 1	1 5 7 9 12 15 27 30 31 38 39 41	42	33	25	
sp 2	9	100			
sp 3	6 15 32 52	100			
Austrogomphus guerini (Hambur)	34 57 59	100			
Austrothemis nigrescens (Martin)	10 19 30 33 62	25		50	25
Ischnura heterostricta (Burmeister)	16 17 18 19 21 27 34 44 45 55 62 63 65		22	78	
Chlorolestidae sp 1	5 10 14 15 16 18 19 60	22		78	
Plecoptera					
Stenoperla australis	6 7 8 10 15 31 32 33 34 41 52 53 60	87	13		
Eusthenia venosa	4 7 11 12	75		25	
Austocerca tasmanica (Tillyard)	19			100	
Austrocercella mariannae	4 6 7 8 11 12 14 18 19 29 30 31 32 40	35	23	31	12
	41 60A				
Notonemoura lynchi Illies	30 31	50	50		
Acruroperla atra	8 12 30 32 33 52 53 54 55	33	8	17	42
Austropentura victoria	4 6 7 11 12 30 32	49	13	13	25
Austroheptura neboissi Illies	7 10 54 55	75			25
A. picta	52 53	67			3
Eunotoperla kershawi	6 7 34	75	25		
Illiesoperla australis	4 6 7 8 9 10 11 12 15 16 17 20 24 26	38	25	33	4
	29 30 31 33 34 35 39 40 41 42 52 53 54				
	55 62				
Neboissoperla alpina	9 10 12 13 15 29 31 33 34 42 52	43	57		
Trinotoperla irrorata	13 52		100		
Newmanoperla thoreyi	34 54	50	50		

Appendix 6 (continued).

Taxa	Sites at which taxa were collected	KS	BS	SS	LP
<u>Leptoperla neboissi</u>	33 35 39 41 55 57	50		50	
<u>L. primitiva</u>	15 16 17 33 38 54 58 63 66	14	28	56	
<u>L. kimminsi</u>	17		100		
<u>Riekoperela tuberculata</u>	4 6 7 8 9 12 13 14 16 29 30 31 32 34 35 52 53 54 55	30	44	19	7
<u>R. rugosa</u>	11 31 41 53	75		25	
<u>R. karki-reticulata</u> gp	4 6 7 8 11 12 30 32 52 54	37	42	16	5
<u>Dinotoperla christinae</u>	4 6 12 29 32 52	14	56	28	
<u>D. arearia</u>	4 6 8 12 14 29 30 32 52 53 54	43	43	14	
<u>D. fontana</u>	6 8 9 10 14 15 16 17 24 26 29 31 33 34 35 40 53 54 55	33	44	17	6
<u>D. serricauda</u>	4 6 7 8 9 11 12 13 14 16 29 30 33 34 35 57 58 62	20	35	45	
Hemiptera					
<u>Microvelia oceanica</u> Distant	5 9 32 47 62			100	
<u>M. distincta</u> Malipatil	5 10 31 33 40 54 60 62			100	
<u>M. peramoena</u> Hale	16 17 18 20 21 22 27 35 38 40 42 43 47 49 51 57 58 62 63		8	92	
<u>M. fluvialis fluvialis</u> Malipatil	42			100	
<u>M. dubia</u> Hale	20 22 26 31 39 43 49 50 51 52 58 62 63		6	94	
<u>Mesovelia hungerfordi</u> Hale	22			100	
<u>Naucoris australicus</u> Stal.	16 22 67			100	
<u>Diplonychus eques</u> (Dufour)	16 22 47			100	
<u>Rheumatometra philarete</u> Kirk	8 16 17 21 26 27 31 33 40 43 49 50 51 53 54 55 57 58 63			100	
<u>Tenagogerris euphrosyne</u> (Kirk)	47 58 65			100	
<u>Gerris antigone</u> Kirk	51 58			100	
<u>Anisops thienemanni</u> Lund.	16 17 20 22 35 43 45 47 50 58 63 65 67			100	
<u>A. deani</u> Brooks	20 45 65 66			100	
<u>A. gratus</u> Hale	27 58 65 67			100	
<u>Anisops</u> spp	44 50			100	
<u>Enithares bergrothi</u> Mont.	57 62 63			100	
<u>Sigara truncatipala</u> (Hale)	16 17 20 21 26 29 35 43 52 55 62 63 67			100	
<u>S. sublaevifrons</u> (Hale)	16 18 22 27 40 55 58 62			100	
<u>Sigara</u> sp	42				
<u>Agraptocorixa eurynome</u> (Kirk)	16 20 27 43 50 62 67				
<u>A. parvipunctata</u> (Hale)	11 14 21 43			100	
<u>Micronecta robusta</u> Hale	17 20 22 47 67			100	
<u>M. annae annae</u> (Kirk)	17 18 20 21 26 31 43 49 50 51 58 62 63			100	
	65 66				
<u>M. batilla</u> Hale	16 20 26 27 35 39 40 42 50 57 62 65			100	
Megaloptera					
<u>Archichauliodes guttiferus</u> Walker	10 12 15 31 32 34 40 52 53 54 60 60A	71	7	7	14
sp 2	15	100			
Neuroptera					
<u>Austroneurorthis</u> sp 1	6 8 9 11 12 15 30 32 52 53 54 60	88		12	
<u>Kempynus</u> sp 1	32 40			100	
Coleoptera					
Haliplidae larvae sp 1	41	100			
Dytiscidae adults					
<u>Sternopriscus mundanus</u> Clk	5 8 30 50 57	20	40	40	
<u>S. multimaculatus</u> Clk	22 41 43 52 61			100	
<u>Australphilus saltus</u> Watts	10 17 32 52 55 62			100	
<u>Necterosoma penicillata</u> Clk	5 10 16 17 18 43 49 53 59 61 65 67	18		82	
<u>Liodessus anablis</u> (Clk)	5 19 30 33 60	40		60	
<u>Chostonectes gigas</u> Boh.	16		50	50	

Appendix 6 (continued).

Taxa	Sites at which taxa were collected	KS	BS	SS	LP
Bidessus bistrigatus Clk	16 21 22 47 51 63		17	83	
Megaporous hamatus (Clk)	22 49 66			100	
Platynectes decempunctatus Fab.	19			100	
Rhantus suturalis (Macleay)	21 61			100	
Antiporous blakei Clk	24			100	
Carabhydrous sp 1	53	100			
Dytiscidae larvae					
Necterosoma sp 1	16			100	
Platynectes sp 1	65	50		50	
sp 2	19			100	
Rhantus sp 1	16 47			100	
sp 2	57			100	
Lancestes (nr) lanceolatus Clk	57			100	
Laccophilus sp 1	11			100	
Gyrinidae adults					
Macrogyrus oblongus apacior	4 19 21 31 38 42 51 52 58 60 63		18	73	9
M. australis (Bruelle)	47			100	
Aulongyus strigosus (Fabr.)	27 38 47 49 51 58 63 65 66	29	28	43	
Hydraenidae adults					
Hydraena luridipennis Macleay	12 52		100		
Ochthebius lividis Deane	40 43 47 50 58 63 65 66 67		20	80	
O. (nr) clypeatus Deane	40 43 47			100	
Hydraenidae larvae sp 1	34			100	
sp 2	Irrigation ditch near Moe		33	67	
Hydrochidae adults					
Hydrochus victoriae	19 50 65		33	67	
sp A	67			100	
sp F	27			100	
Hydrophilidae adults					
Helochares australis Blackburn	4 19 29 47			100	
Paracumus pygmaeus Macleay	4 8 15 19 27 43 45 63 65			100	
Nothydrus australis	1 4 6 7 8 10 12 14 15 16 19 20 30 52 53 54 60 63	8	19	62	12
Enochrus elongatus Macleay	43 47 63 67			100	
Enochrus sp 1	19 43 67			100	
Chaetarthia australis Knisch	43			100	
Limnoxenus zealandicus Brown	67			100	
Berosus involutus Macleay	57			100	
B. (nr) flindersi	18 20 21			100	
Hydrobius sp 1	16			100	
Helodidae larvae sp 1	5 7 10 12 31	27	27	18	27
sp 2	1 9 10 16 20 29 41 43 52 53 54 60	13	13	61	13
Cyphon sp (adult)	54			100	
Psephenidae larvae					
Sclerocyphon maculatus	1 5 6 10 11 12 14 15 28 30 31 34 39 41 52 53 54	68	21	11	
S. striatus	15 33 39 41 53 57 60	83	17		
Ptilodactylidae larvae					
Byrrocryptus sp 1	4 6 7 8 9 12 15 16 32 52 54 60 60A	66	17	11	6
Elmidae larvae					
Kingolus sp L1E	10 14 15 31 34 40	83	17		
sp L5E	55	100			
K. yarrensis	4 8 11 12 30 53 54	50	38	12	

Appendix 6 (continued).

Taxa	Sites at which taxa were collected	KS	BS	SS	LP
Simsonia sp L2E	15 34	50	50		
sp L3E	10 15 29 31 34 41 52 54	72	14	14	
sp L12E	10 34	100			
sp L48E	4 6 12 32	40	60		
S. tasmanica	12	100			
Notriolus maculatus Cart	14 17 54 58	50	50		
N. quadraplagiatus	9 14 16 26 40 41	43	43	14	
N. victoriae	15		100		
Notriolus sp	4 5 12 14 34 35 39 40 41 50 51 52 53 55 59 63	50	30	20	
Austrolimnius sp L10E	4 5 6 7 8 9 10 12 15 29 30 31 32 33 34 40 41 52 53 54 55 60	67	22	11	
sp L13E	12 32 34 41 52 53	100			
sp L39E	12 32 34 41 52 53	100			
sp L40E	34	100			
sp L25E	55	100			
Coxelmis sp	37 51 66	50	50		
Elmidae adults					
K. yarrensis	32	40	60		
Kingolus spp	31 33 34 54 55	45	55		
Simsonia spp	31 32 52 53 54 60A	61	39		
S. hopsoni	60A	60		40	
S. tasmanica	52 60		100		
Notriolus spp	19 23 26 29 31 32 33 34 35 39 50 52 54 55 58 59 60 60A 61 65	12	48	24	2
Austrolimnius spp	19 29 30 31 32 33 34 52 53 54 55 59 60 60A	57	28	15	
Diptera					
Tipulidae sp 1	6 10 11 12 15 34 41 53 60	73	27		
sp 3	10 34 52 57	83	17		
sp 5	57	100			
sp 10	4 7 8 10 12 15 30 32 34 41 52 54	50	33	11	6
sp 20	50		100		
sp 24	5 7 22 35 54 60A	83		17	
sp 30	17 34	50	50		
sp 32	53	100			
sp 34	5	100			
sp 35	5 6 7	100			
Tipulidae sp 36	6 32	100			
sp 37	10			100	
sp 39	61		100		
Psychodidae sp 1	5 6		100		
Dixidae sp 1	1 9 60			100	
sp 2	1 6 7 9 12 32 52 53 60			100	
Culicidae sp 1	22			100	
Rheocricotopus sp 1	5 10 14 33 38 41 59	63	37		
nr. *Eukiefferiella* sp 1	4 5 6 7 8 9 10 11 12 13 14 29 30 31 32 33 50 52 53 54 60	45	39	11	5
Thienemaniella sp 1	6 7 10 11 12 14 15 16 20 24 29 33 34 35 39 41 42 50 52 54 57 59 60 66	50	10	40	
Cricotopus sp 1	1 4 5 6 7 8 9 10 11 12 13 14 15 18 22 29 31 32 33 34 35 37 38 52 53 54 55 56 57 58 60 60A 62 63 66	42	32	26	
sp 3	7	100			
Symbiocladius aurifodinae	8 10	100			
Psectrocladius sp 1	58 59 63	33	33	33	
nr *Cordites* sp 1	10 12 30 34 53 55 57 59	90	10		

Appendix 6 (continued).

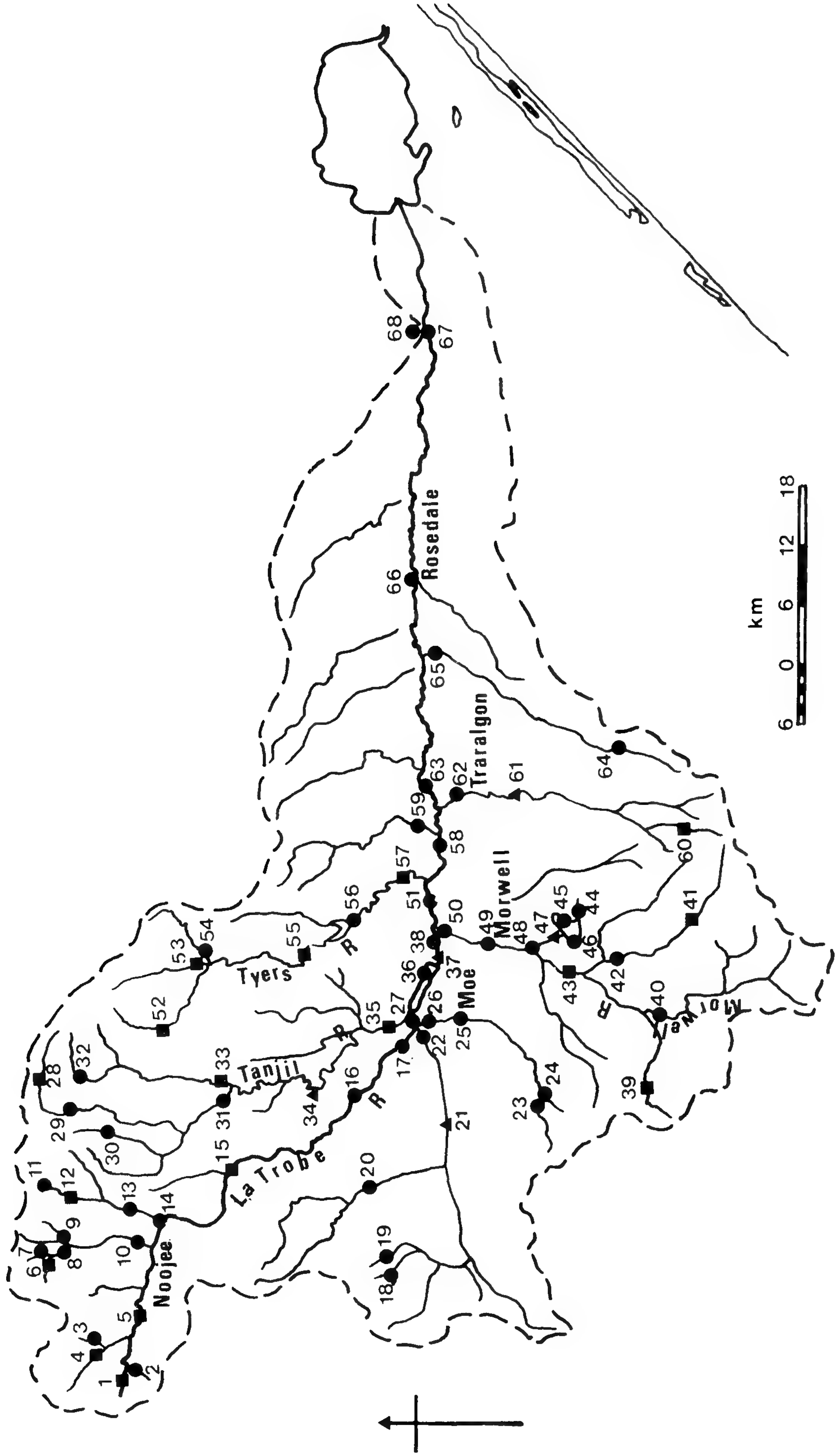
Taxa	Sites at which taxa were collected	KS	BS	SS	LP
Orthocladiinae sp 39E	7 10 13 15 29 31 33 37 41 50 52 54 56 60	58	42		
sp 103E	1 4 7 11 12 16 18 31 37 38 41 44 45 47 49 5[illegible] [illegible]1 56 57 60 60A 62	34	29	34	3
sp 117E	52	100			
Riethia sp 1	5 7 9 10 14 15 22 31 34 50 52 53 54 55 56	53	26	21	
Cryptochironomus grisiedorsum	33		100		
nr Saetheria sp 1	56 57	100			
Polypedilum sp 1	4 8 11 14 15 16 17 18 20 21 22 24 26 31 33 34 35 37 38 40 41 43 49 50 51 52 53 54 56 59 60 62 63 67	25	18	55	2
sp 7	60	100			
Xenochironomus sp 1	5	100			
Kiefferulus maritini Freeman	16 37	50		50	
?Chironomus sp 4	16 37	50		50	
Parachironomus sp 1	18 22 26	33		67	
sp 3	17 18 53	67		33	
Paraborniella sp 1	41 60	100			
Chironomini sp 3E	4 5		50	50	
sp 34E	9	100			
Rheotanytarsus p 1	6 10 11 12 14 15 16 18 30 31 32 33 34 35 40 44 53 54 55 57 59 60	47	20	33	
?Calopsectra sp 1	5 19	50		50	
Micropsectra sp 1	4 12 16 18 19 38 41 50 57 60 60A	40	7	53	
Tanytarsini sp 53E	4 10	50	50		
Ablabesmyia sp 1	31	50		25	25
Macropelopia sp 1	1 7 12 14	25		75	
Pentaneura sp 1	5 9 10 11 12 14 16 19 20 31 33 39 41 52 53 54 56 57 59 60 60A 61	46	9	43	2
Procladius sp 1	11 16 19 42 60 60A	40		60	
Aphroteniinae sp 18E	10 33 53 54	100			
Paraheptagyia sp 1	31 37	75	25		
Podonomopsis sp 1	6 7 8 12 13 14 29 30 31 32 33 53 54 56 57	61	35	4	
Podonomus sp 1	5 60	75		25	
Nilobezzia sp 1	8 10 11 14 16 30 32 41 54 60	38	38	24	
Alludomyia sp 1	6 16 35	50		50	
Dasyhelea sp 1	5 11	50		50	
sp 2	4 5 13A	33	67		
nr. Atrichopogon sp 1	47		100		
Bezzia sp 1	60			100	
Austrosimulium montanum	1 6 8 11 12 29 30 32	14	14	58	14
A. victoriae	6 12 15 29 32 41 52 53 54 60 60A	41	36	18	5
A. furiosum	10 12 15 16 17 18 19 20 26 31 33 34 35 41 49 50 53 54 55 56 57 59 60 60A 63 66	42	14	42	2
Simulium ornatipes Skuse	38 47 51 65		40	60	
Cnephia aurantiacum	6 7 8 12 13 29	44	44	12	
Thaumaleidae sp 1	6 8		50	50	
sp 2	9		100		
sp 3	40				100

Appendix 6 (continued).

Taxa	Sites at which taxa were collected	KS	BS	SS	LP
Edwardsina alticola? A	13 29 31	67	33		
? B	6 13 29 31	75	25		
? C	15	100			
E. williamsi Zwick	15 29	100			
E. affinis	6 7	100			
E. polymorpha	12 15 29 31 33 34	83	17		
Austrocurupira nicholsoni(Tillyard)	29	100			
Apistomyia tonnoiri	13 29	50	50		
Athericidae sp 4	6 9 10 15 16 31 34 53 54	63	37		
Tabanidae sp 1	32	100			
Stratiomyidae sp 3	16 47 51		33	67	
Empididae sp 2	4 7 8 9 10 11 12 14 32 34 41 52 54 57 58 60 61	52	38	5	5
sp 3	39 57	100			
sp 5	9 11 12 32	100			
Ephydridae sp 2	5	100			
Muscidae sp 1	51 67			100	
Trichoptera					
Ethochorema sp 1	1 4 6 7 11 12 30 32 33 52	44	31	19	6
Ethochorema gp	5 6 7 8 10 12 15 16 18 19 24 30 31 32 33 34 35 39 40 41 42 52 53 54 55 56 57 59 60 60A 61 63 65	53	20	20	7
Taschorema rugulum	12	100			
Austrochorema sp 2	6 7 11 12 30	30	20	30	20
Apsilochorema obliquum	8 11 12 15 20 32 34 41 54 60 60A 61	53	13	27	7
Psyllobettina locula	6 12	92	8		
P. nr cumberlandica	13		100		
Ulmerochorema gp	1 6 7 9 10 14 15 29 31 34 41 52 54 56 57 58 60 60A 66	48	35	17	
U. onychion Neboiss	59	100			
Agapetus sp 1	4 6 7 8 9 10 12 15 30 32 41 49 50 52 53 54 56	68	32		
sp 2	6 7 8	100			
Hydroptila sp 1	4		67	33	
Orthotrichia atraseta	6 14 15	50	50		
Maydenoptila cuneola	15 53	100			
Hellyethira (?simplex)	18 19			67	33
Hydroptilidae sp 5	41	100			
Hydrobiosella sp 1	6 7 8 9 11 12 14 30 31 32 33 53 54 56	67	22	6	6
Hydrobiosella sp 2	12	100			
?Ecnomina sp 1	11 14 15 33 37		33	67	
sp 2	34	100			
sp 4	55	100			
Ecnomus sp 1	5 15 16	100			
Ecnomus spp	38 40 47 63	20	60	20	
Polycentropodidae sp 1	11 15	75	25		
sp 2	4 33	75		75	
sp 4	14		100		
Austropsyche sp 1	1 5 6 7 11 30 32 60	40	20	35	5
?Smicrophylax sp 1	5 8 10 14 15 32 34 35 52 53 54 55 57	37	42	21	
Asmicridea edwardsi	8 10 13 27 31 32 34 35 37 38 41 42 50 51 52 54 57 58 59 63 66	22	56	22	
Cheumatopsyche sp 1	31 37 38 50 51 54 58 63 66	40	20	40	
Helicopsyche sp 1	33	100			
Alloecella grisea	1 4 5 6 7 11 12 29 31 32 53 55	24	48	28	
Helicophidae sp 2	1 5 7 11 12 29 31 32 53 55	22	44	33	

Appendix 6 (continued).

Taxa	Sites at which taxa were collected	KS	BS	SS	LP
Conoesucus sp 1	1 4 5 6 7 8 9 10 11 12 13 14 15 29 31 32 34 35 52 53 54	33	50	17	
Conoesucidae sp 3	6 7 8 9 12 32 53 55	55	18	18	9
sp 4	6			100	
sp 5	8 9 10 12 32 41 52 53	44		33	22
sp 6	10 13 14 15 16 31 34	38	25	38	
sp 7	5 10 12 14	40	60		
sp 8	30			100	
sp 9	5 14 15 16 17 19 24 41 52 55 61	25	33	42	
Coenota plicata	1 6 7 8 9 12 29 31 32 53	38	6	38	19
Anisocentropus sp 1	33 55 57	25	25	25	25
Philorheithridae sp 1	5 6 8 10 24 32 33	45	36	9	9
sp 2	6 17	50	50		
sp 3	8 10	100			
sp 4	1 55		33	67	
sp 5	1 5 6 39		43	43	14
sp 6	8 41	100			
Notalina bifaria	5 8 10 14 15 16 17 18 23 29 31 33 34 35 40 41 52 53 54 55 57 60 61	27	12	49	12
Triplectides sp 2	57 60 65	50		50	
sp 3	1 14 15 16 17 20 21 22 24 35 50 53 55 58 67	6	6	88	
T. ? proximus	4 6 8 9 10 12 30 31 32 33	8	8	67	17
Oecetis sp 1	51	50	50		
Condocerus paludosus	1 4 5 6 7 9 10 11 12 14 15 16 17 29 30 31 32 33 52 53 54	11	18	68	3
Atriplectides dubia	23	100			


Rosedale
Traralgon
Morwell
Moe
Noojee
La Trobe R
Tanjil
Tyers R
R
km
6 0 6 12 18

Appendix 7. Taxa restricted to logs and the sites at which they occurred. Data are from all visits. (A) adults.

Species	Site
Atalonella sp. 5	28
A. sp. 6	4
Austrocerca tasmanica (Tillyard)	28
Cyphon sp. 2	4, 43
Simsonia sp. L12E	53
Notriolus sp. L9E	39
S. tonnoiri (A)	4, 5
N. victoriae (A)	43, 52
N. taylori (A)	15, 33, 35, 39, 55

Species	site
Paraheptagyia sp. 1	28, 53
Microchironomus sp. 1	1
Dolichopodidae sp. 1	43
Empididae sp. 7	28
Empididae sp. 8	28
Ulmerochorema onychion Neboiss	35
Ecnomina sp. 3	28
Nyctiophylax sp. 1	33

Appendix 8. The common (>0.5% of individuals) taxa on each visit and from all samples.

	May 1979	Aug 1979	Nov 1979	Feb 1980	May 1980	Nov 1980	All samples
Atophlebioides sp. 1	x	x	x	x	x	x	x
A. sp. 3	x	x	x	x	x	x	x
Atalonella sp. 2	x	x	x	x	x	x	x
Baetis sp. 3	x	x	x	x	x	x	x
Austrolimnius L10E	x	x	x	x	x	x	x
Austrolimnius adults unident.	x	x	x	x	x	x	x
Tipulidae sp. 1	x	x	x	x	x	x	x
Rheotanytarsus sp. 1	x	x	x	x	x	x	x
Riethia sp. 1	x	x	x	x	x	x	x
nr *Cordites* sp. 1	x	x	x	x	x	x	x
Thienemaniella sp. 1	x	x	x	x	x	x	x
Cricotopus sp. 1	x	x	x	x	x	x	x
?*Eukiefferiella* sp. 1	x	x	x	x	x	x	x
Polypedilum sp. 1	x	x	x	x	x	x	x
?*Calopsectra* sp. 1	x	x	x	x	x	x	x
Pentaneura sp. 1	x	x	x	x	x	x	x
Chironomidae immature	x	x	x	x	x	x	x
Leptophlebiidae immature	x	x	x	x	x	x	x
Leptoceridae immature	x	x	x	x	x	x	x
Hydracarina unidentified	x	x	x	x	x	x	x
Potomopyrgus niger		x	x	x	x	x	x
Tasmanocoenis sp. 2	x	x	x	x	x		x
Austrosimulium furiosum	x	x	x	x		x	x
Agapetus sp. 1	x	x	x		x	x	x
Austrolimnius sp. L13E	x		x	x		x	x
Podonomopsis sp. 1	x	x	x			x	x
Austrosimulium victoriae	x	x	x	x			x
Baetis sp. 1	x		x	x			x
Cyphon sp. 1	x			x	x		x
Podonomus sp. 1	x	x					
?*Parachironomus* sp. 3	x		x		x		x
Micropsectra sp. 1					x	x	
Stempellina nr *bausei* sp. 1		x	x				x
Procladius sp. 1		x				x	
nr *Eukiefferiella* sp. 1		x	x			x	x
?*Skusella* sp. 1	x	x	x		x		x
Corynoneura sp. 1			x	x		x	
Chironomidae pupae				x		x	
Pseudomoera gabrieli						x	
Austrocercella mariannae			x			x	x
Riekoperla rugosa					x		
R. karki-reticulata		x					
Simsonia sp. L3E		x					
Nilobezzia sp. 1		x		x			
Bezzia sp. 1						x	
Edwardsina polymorpha			x			x	
Ecnomus sp. 1					x		
Ecnomus spp.	x	x			x		
Asmicridea edwardsi				x		x	
Cheumatopsyche sp. 1	x	x x x					
Conoesucus sp. 1					x		
Conoesucidae sp. 9		x					
Notalina bifaria	x	x	x				x
Baetis immature	x		x	x			x
Gripopterygidae immature	x						
Hydropsychidae immature				x			
Conoesucidae sp. 13				x			
Simuliidae immature					x	x	x
Gastropoda unidentified				x			
Corynoneura sp. 2				x			
Orthocladiinae sp. 124E						x	
Austrolimnius immature					x	x	x
Cyphon sp. 5					x		
Total number of taxa	36	37	37	37	35	38	39

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A distribution list for the aquatic invertebrates in the lowland region of the LaTrobe River, Victoria

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Abstract. Marchant, R., Mitchell, P. and Norris, R. (1984) A distribution list for the aquatic invertebrates in the lowland region of the LaTrobe River, Victoria. *Occ. Pap. Mus. Vic.* 1: 63-79.
A list of the taxa and their abundances at ten sites on the LaTrobe River, two sites on the Thomson River and one site on the Morwell River is given.

Introduction

The lowland reach of the LaTrobe River flows entirely through industrial and agricultural areas. An analysis of the distribution of aquatic invertebrates at ten sites along about 100 km of this section and of the factors influencing this distribution has been published elsewhere (Marchant et al., 1984). In that paper the distribution of only the common (more than 0.5% of total numbers) species was tabulated. Here we present, without comment, the distributional data for all taxa recorded in that study in the belief that such information is valuable when so little is known about the aquatic invertebrate fauna of streams and rivers in SE. Australia.

Fig. 1 indicates the position of the sampling sites. Table 1 gives the total number of specimens of each taxon recorded at each site during the study. Data are also provided on three additional sites (11, 12, 13). Sites 1-10 were sampled on 12 occasions during the two years of the study (May 1979 - March 1981), sites 11 and 12 on only six occasions during one year (May 1980 - March 1981) and site 13 was sampled only twice (January and March 1981). Sites 11, 12 and 13 were not included in the analysis of Marchant et al. (1984). Sites 11 and 12 were well downstream in the lowland reach of the Thomson River. Both sites had a sandy substratum similar to that at sites 1-10 and were located in agricultural land. The faunal composition at these sites showed some similarity on most sampling occasions to that at sites 1-10, but was not consistently associated (using Czekanowski's coefficient of similarity, Hellawell, 1978) with any particular site or group of sites. It was originally thought that the two sites might be most comparable with site 10, but without the influence of the industrial disturbances upstream. At site 13 on the lowland reach of the Morwell River the substratum was clay. As a result the faunal composition at this site was distinct from that at the other sites. The discharge of sewage and saline water to the river just above this site probably also contributed to its distinctiveness.

Acknowledgements

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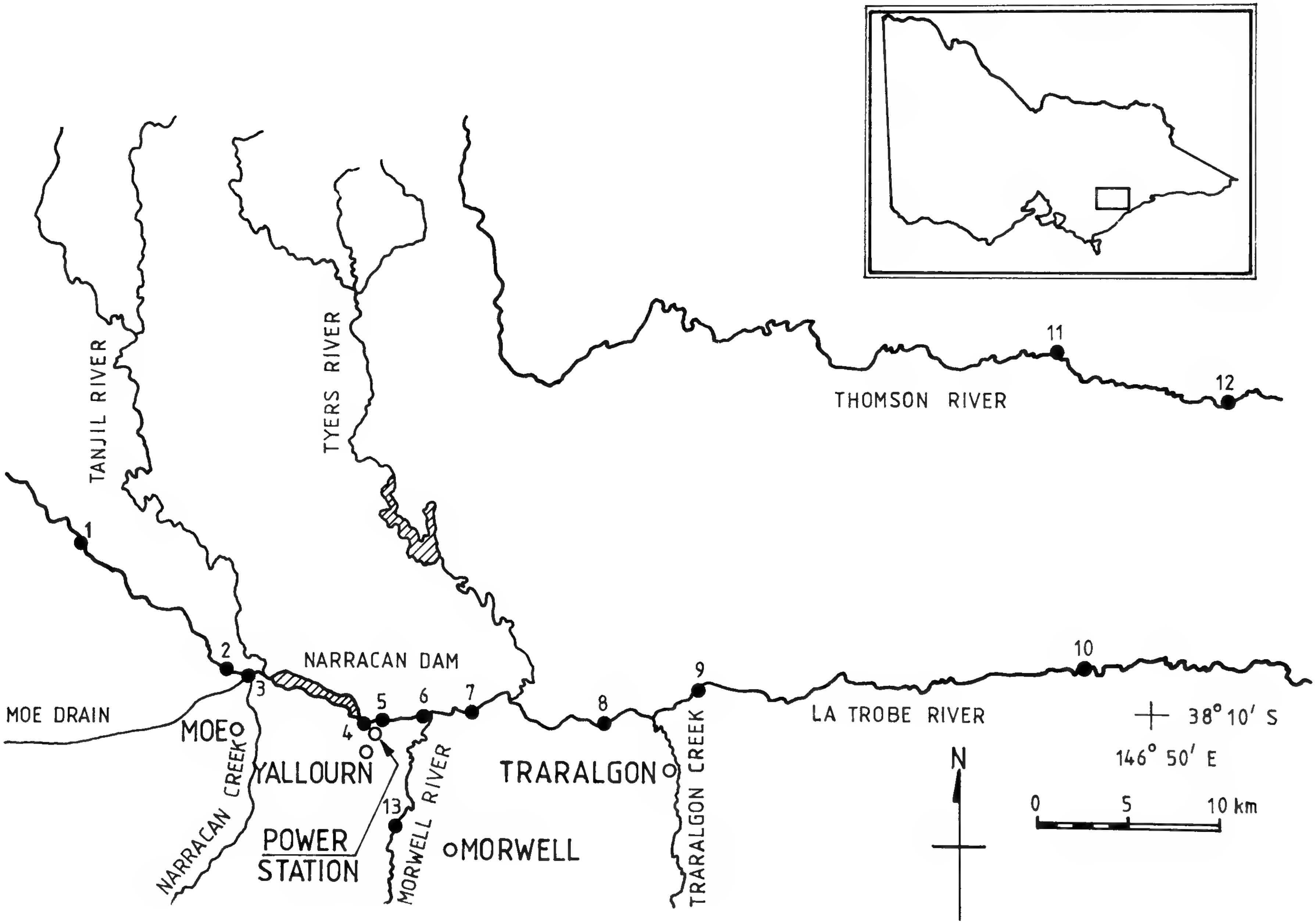

Fig. 1. Sampling locations in the lowland region of the LaTrobe River.

Table 1. A systematic list of the taxa and their abundances in two habitats (main channel and bank) at each site. The nomenclature is that used in the voucher collection of the Biological Survey Department, Museum of Victoria. A = adults.

A. Main channel

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
TRICLADIDA													
Dugesiidae													
Cura pinguis (Weiss)	3	3		14	20				1	8		11	
TURBELLARIA													
Turbellaria sp LTCS1	28	1		6	10	2		1		47		21	4
TRICLADIDA													
Tricladida unidentified	37	1											
OLIGOCHAETA													
Oligochaeta spp	10998	8777	11934	6782	7508	12950	3019	1805	912	6664	10129	45479	1545
HIRUDINEA													
Erpobdellidae sp. 1					2								
Hirudinea unidentified							7						
BIVALVIA													
Corbiculidae													
Corbiculina australis (Deshayes)	1	1	3	63	179	96	80	453	205	1083	70	154	9841
GASTROPODA													
Ancylidae													
Ferrissia tasmanica (Tenison-Woods)	2		1	1	32	6							
F. petterdi (Johnston)				1		1							
Ferrissia immature						1							
Planorbidae													
Physastra gibbosa (Gould)		2	2				1	1	2	11	3	66	4
Gyraulus scottianus (Johnston)	1	1											
Hydrobiidae													
Potomopyrgus niger (Quoy & Gaimard)				4									
Lymnaeide													
Pseudosuccinea columella (Say)	1												
Succineidae													
Succinea australis (Ferussac)										1			
Gastropoda unidentified	1	1	2	33	14	1						1	3
HYDRACARINA													
Hydracarina sp. 1	18	1	11							1	1		
sp. 2	4		1					2		1	1	14	
sp. 4	9		1								10		
sp. 5	28	122	55		6	1	8	2			284	846	4
sp. 6	26	3	2								2	1	
sp. 7	222	24	4				1				10	1	7
sp. 9	1		1							1	1		
Australiobates sp. 1	196	17	59	3	4		2	2		1	196	3	10
Hydracarina sp 10	99	1											
sp. 15											2	23	
sp. 17	358	32	176			1				1	58	42	46
sp. 19	9	1	1		6	5		17	3		22	70	65
sp. 20	1												
sp. 21	408	154	5										
sp. 22	56	54											

Table 1A (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
sp. 23	29	1											
sp. 24	2		2								14		
sp. 31						1							
sp. 32						1							
sp. 33											1		
sp. 34											35	31	
sp. 38	4												
sp. 39											1	2	
Hydracarina unidentified	63	3		1							2	21	4
AMPHIPODA													
Ceinidae													
Austrochiltonia australis Sayce			2	8	1	15	1		1				1
Gammaridae unidentified													4
DECAPODA													
Atyidae													
Paratya australiensis (Kemp)		1		209	26	13	1						
SYNCARIDA													
Syncarida unidentified	70												
ISOPODA													
Janiridae													
Heterias sp. 1	2											41	
EPHEMEROPTERA													
Oligoneuriidae													
Coloburiscoides spp	14	6	4									11	
Siphlonuridae													
Tasmanophlebia lacuscoerulei Tillyard	10		2										
Leptophlebiidae													
Atalophlebioides sp. 1	286	4	13		1								
sp. 2	1												
A. pusillum (Harker) (sp. 3)	52	3	2	3							1		
sp. 4	2909	276	8	1							12		
Atalonella sp. 2	707	38	9	12	1						12	21	
sp. 4	1505	29	11	1		1					2		
Atalophlebia (nr) *longicaudata*	3	1		1						1	1		
sp. 2	13										1		
A. australis (Walker)				1									
sp. 4			1	8		3					35		
Jappa sp. 1	8		2										
sp. 3											1		
Leptophlebiidae immature	3067	339	123	29	20	5		2		2	24	1	
Caenidae													
Tasmanocoenis tonnoiri Lestage	52	7	78	43	37	400	419	2130	118	5288	14766	29835	2
sp. 3										1	14	20	
Baetidae													
Baetis sp. 3	3	1									1		
sp. 4	647	32	35	1	2	5	3	2			1		1
sp. 5	1		1			49	59	7	5	9	2		1
sp. 6	1	1	3	1		175		9		1		1	
Centroptilum sp. 1						1	1						
Baetidae immature	108	13	13	7	12	86	20	12	14	47	14	31	14

Table 1A (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
ODONATA													
Gomphidae immature			1								10		
Synthemidae sp. 1										1			
Coenagrionidae immature				1									
Chlorolestidae sp. 2	10												
Lestidae sp. 1	1												
Protoneuridae sp. 1										1			
PLECOPTERA													
Eusthenidae													
<u>Stenoperla australis</u> Tillyard	3												
Notonemouridae													
<u>Austrocercella mariannae</u> Illies	2												
Austroperlidae													
<u>Austropentura victoria</u> Illies	1	1										10	
<u>Austroheptura picta</u> (Riek)	3		1										
Austroperlidae immature	1		1										
Gripopterygidae													
<u>Trinotoperla yeoi</u> Perkins	1				1								
<u>Newmanoperla thoreyi</u> McLellan			1			89			2	3	16		
<u>Leptoperla neboissi</u> McLellan									1	1	10		
<u>L. primitiva</u> McLellan	0	0		2	1	8				1	61	1	
<u>Riekoperla tuberculata</u> McLellan		3				3					3		
<u>Dinotoperla arenaria</u> Hynes	2												
<u>D. fontana</u> Kimmins	1											10	
<u>D. serricauda</u> Kimmins		1				1	1					12	
<u>D. brevipennis</u> Kimmi	2		1										
Gripopterygidae immature	18	3	2	2	4	36	1	3	2	16	123	25	
Plecoptera immature	6											10	
HEMIPTERA													
Veliidae													
<u>Microvelia oceanica</u> Distant									1				
Mesoveliidae													
<u>Mesovelia hungerfordi</u> Hale											1		
Corixidae													
<u>Micronecta batilla</u> Hale						2						10	
Corixidae immature	1	1	2	1		2	4	9	4	9	93	40	1
MEGALOPTERA													
Corydalidae													
<u>Archichauliodes</u> sp. 1	2												
sp. 2	4	1										1	
COLEOPTERA													
Dytiscidae													
<u>Carabhydrous niger</u> (A)	1												
sp. 2 (A)	7												
<u>Sternopriscus</u> sp. 1	23												
Gyrinidae													
<u>Macrogyrus oblongus apacior</u> Blackburn (A)						1							
<u>M. oblongus apacior</u>						1							
Gyrinidae immature						1			1				
Hydraenidae													
<u>Ochthebius</u> sp. 1 (A)	2												
Hydraenidae sp. 1	1												

Table 1A (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Helodidae													
Cyphon sp. 1	1857	31	5			1							
Cyphon sp. 1 (A)	6												
Helodidae unidentified (A)	4	1											
Psephenidae													
Sclerocyphon basicollis Lea				1									
Psephenidae immature	1		1										
Elmidae													
Kingolus sp. L1E	12												1
sp. L5E	5											3	
sp. L68E													3
Simsonia sp. L2E													1
sp. L3E			1							1			1
S. hopsoni Cart. & Zeck				1		1					11	11	
S. tasmanica Blackburn					1								1
Simsonia immature	1												
Notriolus maculatus Cart.		1	1	2				1		26			
N. quadraplagiatus Cart.		2	1	1				1		2	2		2
N. victoriae Cart. & Zeck	1	1		1		1					1		
N. allynensis Cart.				1						21			
Notriolus immature	1			2	1		1			6	3		
Austrolimnius sp. L10E	425	23	6			9		4			82		1
sp. L13E											13	21	
sp. L14E											50		
sp. L25E	41	3	9								41	42	1
sp. L34E											15	15	
sp. L40E	1												
sp. L57E											1		
sp. L58E	14	2				1					1		
sp. L62E											295	116	
sp. L64E	4										386	1	
sp. L65E				1							6		
Austrolimnius immature	62	4	11			1					.274	110	5
Coxelmis novemnotata King					3			1		27			
C. v-fasciata Lea										13			
Coxelmis immature										2			
Genus A sp. L15E	188	31	7		4								
Elmidae immature	8				1				1		51	27	1
Simsonia hopsoni (A)											1		
S. leai Cart. & Zeck (A)	1												
S. purpurea Cart. (A)	1												
Simsonia unidentified (A)	5												
Notriolus maculatus (A)	1	2									1		
N. quadraplagiatus (A)	16					1						2	
N. victoriae (A)				1						1		10	
N. allynensis (A)			1										
Austrolimnius sp. 3 (A)	27		3								29	6	
sp. 5 (A)	11		1					2			26	11	
sp. 6 (A)	15	1									55	60	
Austrolimnius unidentified (A)						1							
Coxelmis novemnotata (A)				17	1					2		1	
C. v-fasciata (A)										1			

Table 1A (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
DIPTERA													
Tipulidae sp. 1	95	16	7								25	2	
sp. 2						1							
sp. 3	162	130	45			3					1		
sp. 5	1								1			1	
sp. 10	2	10	9		1		2						
sp. 17	2	2											
sp. 24	29		1										
sp. 27							1						
sp. 29	1												
sp. 30	1												
Tipulidae sp. 32	1												
Tipulidae sp. 47	6		1										
Tipulidae immature	31		1										
Psychodidae sp. 2													1
sp. 3	2												
sp. 4	1												
Chironomidae													
(Orthocladiinae)													
?*Rheocricotopus* sp. 1	47	4	59	10	33	81	1	1			1	203	
nr *Eukiefferiella* sp. 1			1	1	1	50		1					
sp. 2						95							
?*Eukiefferiella* sp. 1	621	148	2316	405	467	1157	1087	318	61	833	478	2019	
Thienemaniella sp. 1	626	110	242	52	86	147			1	2	14	1	
Cricotopus sp. 1	666	15	2111	70	2706	2054	514	87	12	28	213	647	21
Corynoneurea sp. 1	1229	1045	386	20	3				1	1	10		
sp. 2								1					
Psectrocladius sp. 1	12	8	37	28	10	16	140	5	1	3	40		6
nr *Eurycnemus* sp. 1				1	1	1							
nr *Cordites* sp. 1	3872	1380	2527	3	5	38	25	3	2	1	3	2	
Orthocladiinae sp. 39E					29	5							
sp. 103E				5	66	394	22	2	134	2			16
sp. 117E	2												
sp. 142E		3	1	1	1	1							
sp. 154E				1								50	
(Chironomini)													
Dicrotendipes sp. 1										1	1		
sp. 2				1		4					31		
Riethia sp. 1	4583	114	61	311	36	37	16	3	3	5	164		5
Cryptochironomus grisiedorsum (Kieffer)	45	19	66	73	32	106	37	26	2	95	18	7	4
nr *Saetheria* sp. 1	90	546	3			2076	96	31	15	39	19		
Polypedilum sp. 1	237	176	1567	66	36	244	237	24	60	879	409	68	13
sp. 6			1	1	1	4	56	38	30	255	187		
Harnischia gp sp. 1	13										10		
sp. 2	16	21	172	16		9	34	32	1	317	1	1	
Skusella sp. 1	8												
?*Xenochironomus* sp. 1				2	1	13							
Kiefferulus martini Freeman				1									
Chironomus cloacalis Atchley & Martin											10		
?*Chironomus* sp. 2						2				2			
Chironomus sp. 4		5	4	31		44	24	10	25		21		1
Parachironomus sp. 1				3	24	8	1		12	28			1
?*Parachironomus* sp. 2	177	281			1								
sp. 3	24	124	4	2			1	2	2	1			
Paraborniella sp. 1	15		2		1					1	3		

Table 1A (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
?Microchironomus sp. 1				55	12	6	20	10	7	16			2
Chironomini sp. 3E			4	2	2					1			
sp. 148E	2	3	2	1									
sp. 161E											1		
(Tanytarsini)													
Rheotanytarsus sp. 1	15	6	263	125	135	736	80	20	6	136	100	602	36
?Calopsectra sp. 1	1794	230	3565	202	83	83	319	149	22	154	2465	1241	28
Micropsectra sp. 1	41	2	27	75	21	2				52	11		
Stempellina nr bausei sp. 1	143	10	68										
Tanytarsini sp. 122E		11	10	176	61	131	138	424	196	66	3430	125	48
(Tanypodinae)													
Ablabesmyia sp.		1	1	1					1		274	22	
Macropelopia sp. 1		1											
Pentaneura sp. 1	3253	132	35	58	26	23	2	1		1	1	2	
Procladius sp. 1	12	2	10	267	3	22	9	3	1	13	1648	75	1
Coelopymia pruinosa Freeman													
Tanypodinae sp. 108E				2	1		1				9	3	
sp. LTCS15	15	11											
Aphroteniinae sp. 18E											82	13	
(Diamesinae)	411	3	9	1						1	5	5	
Paraheptagyia sp. 1													
(Podonominae)							1						
Podonomopsis sp. 1													
Podonomus sp. 1	1				4								
Chironomidae pupae	261	209	13	2	1								
immature	50	1				1	13	14	4	9			
Ceratopogonidae	257	11	9	38	5	47	4	64	10	18	173	126	27
Dasyhelea sp. 1													
sp. 2	393	533	2	1									
Nilobezzia sp. 1	3												
Alludomyia sp. 1	44	6	2	1						1	1		
Bezzia sp. 1												1	
nr. Forcipomyia sp. 1	2			1									
Ceratopogonidae sp. 11	1							1					
sp. 15	14	3	9	1	1								
sp. 17					1								
Ceratopogonidae immature	1												
Simuliidae													
Austrosimulium furiosum Skuse	1	1	6			2			1	4	1	1	2
A. montanum Mackerras & Mackerras													1
Simulium ornatipes Skuse	3					14				1			11
Simuliidae immature	18	1	7		1	4			2	1		2	2
Blephariceridae													
Edwarsina polymorpha Zwick	65	7	10										
Tabanidae sp. 1			11										
sp. 2	4												
sp. 3	118	9	424	2	3	116	57	38	1	47	274	563	71
Dolichopodidae sp. 1			1										
TRICHOPTERA													
HYDROBIOSIDAE													
Ethochorema gp (sp. 4)	27		2										
Austrochorema sp. 1						1							
Apsilochorema obliquum Mosely	4												
Ulmerochorema gp sp. 1					1							1	
U. onychion Neboiss	10									2			
Tanjilana sp. 1	37	3									1		
Hydrobiosidae immature	66		1									2	

Table 1A (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Glossosomatidae	3		10					1					
Agapetus sp. 1				1									
sp. 2	5	1											
Glossosomatidae immature													
Hydroptilidae						2						13	
Hydroptila (?scamanda)	3					3							
Orthotrichia atraseta Wells	1					2							
Hellyethria ?simplex												1	
sp.1		1	10			1	2						
sp.2						150	1					4	
Oxyethira columba (Neboiss)	53												
Hydroptilidae sp.5	3		2			4		1			11		
Hydroptilidae immature													
Philopotamidae	3												
Hydrobiosella sp.1	2												
Philopotamidae immature	28	1	10	1	1								
?Ecnomina sp.1						3							
sp.2	56	2	1										
sp.4		8	48	615	4159	7380	716	968	20	42	167	69	4
Ecnomus spp	1				5						10	1	
Ecnomidae immature													
Polycentropodidae	3												
Plectrocnemia sp. 1	2												
Polycentropodidae immature													
Hydropsychidae	1												
Smicrophylax sp. 1	2	1	1		8	55	3	1	1		11	14	
Asmicridea edwardsi (McLachlan)	13	1	17		284	1199	54	10	3	16		2	9
Cheumatopsyche sp. 1	47					21	5		5		1	1	
sp. 2	162	19											
sp. 4		2	1		13	398	1	2	15		16	3	8
Hydropsychidae immature													
Kokiriidae	3		28										
Tanjistomella verna Neboiss													
Helicophidae immature							4						
Conoesucidae													
Costora delora Mosely	1												
Conoesucidae sp. 4										1			
sp. 9		1									2	1	
sp. 10												10	
Conoesucidae immature	8		2										1
Tamasia variegata Mosely	2		1										
Anisocentropus sp. 1				1			1						
Philorheithridae sp. 1	1	1											
sp. 2	1												
Philorheithridae immature	1		2		1	2				1			
Odontoceridae sp. 1				4									
Leptoceridae	46	1	1	3	1			6					
Notalina bifaria Neboiss											5		
N. fulva Kimmins (Type A)	4	1	1										
N. fulva Kimmins (Type B)	3		1			2							
Triplectides sp. 1										1			
sp 2		1	1		6	5	21			7	1		
Oecetis sp. 1			1	1		4					1		2
sp. 2			1										
sp. 3					1								
Leptoceridae sp. 5E	121	17	11	2	2	26	10	16	7	34	11		15
Leptoceridae immature													
Atriplectidae	2												
Atriplectides dubia Mosely	11									1		1	
Trichoptera immature													

Table 1 (continued).
B. Banks

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
TRICLADIDA													
Dugesiidae													
Cura pinguis (Weiss)	32	25	48	22	44	1		10	16	392	13	11	
TURBELLARIA													
Turbellaria sp. LTCS1	8		45	6	30	7	1	2		2910	1	1	
NEMATOMORPHA													
Gordiidae													
Gordius sp. 1	1												
OLIGOCHAETA													
Oligochaeta spp.	14606	25867	25498	7556	8142	7605	6089	8158	21398	25845	12218	37548	597
HIRUDINEA													
Erpobdellidae sp. 1				1	2			1		2	10		
Ozobranchidae sp. 1	18		23		1								
Hirudinea unidentified		1											
BIVALVIA													
Corbiculidae													
Corbiculina australis (Deshayes)	110	21	4	551	154	32	19	207	125	245	98	32	2359
GASTROPODA													
Ancylidae													
Ferrissia tasmanica (Tenison-Woods)				1							1		
F. petterdi (Johnson)	3		1		1					2			
Ferrissia immature									1				
Planorbidae													
Physastra gibbosa (Gould)	1	9	41	1	9	10	3	78	26	35	1	85	
Gyraulus scottianus (Johnson)		4			1			1					
Hydrobiidae													
Potomopyrgus niger (Quoy & Gaimard)						2		2					
Lymnaeidae													
Pseudosuccinea columella (Say)		1											
Gastropoda unidentified	1	4			1			1		13		1	
HYDRACARINA													
Hydracarina sp. 1	25	10								1			
sp. 2	7	8	3		1					2		40	
sp. 4	16	6		1									
sp. 5	113	46		2		1		1	1	3	8	324	
sp. 6	12	21		1						1		1	
sp. 7	23	24	1								10		
sp. 9	24	8	5				1	2	5	8			
Australiobates sp. 1	334	290	11	2			1			1	149	137	
sp. 10	3	1	1				1						
sp. 13							1						
sp. 15	25		1								11	2	
sp. 16	12	2	3										
sp. 17	247	86	8								74	22	
sp. 18	1									1			
sp. 19	2	2	1	1	4	3		2		90	10	223	50
sp. 20												23	
sp. 21	26	4											
sp. 22	1												
sp. 24		2									20	22	

Table 1B (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
sp. 27	1	1	2										
sp. 30	1	2											
sp. 32												10	
sp. 33					1								
sp. 34											25	30	
sp. 36												10	
sp. 39											22	11	
Hydracarina unidentified	4	1	1		2				1	1	12	1	
AMPHIPODA													
Ceinidae													
Austrochiltonia australis Sayce	13	14	9	5	2	12		3	14	10		1	
Gammaridae unidentified		1	3					11		11			
DECAPODA													
ATYIDAE													
Paratya australiensis (Kemp)	2	33	15	324	103	22	4	7		14		1	
Parastacidae sp. 1	1												
SYNCARIDA													
Syncarida unidentified		2	1							3			
ISOPODA													
Janiridae													
Heterias sp. 1			3								10		
EPHEMEROPTERA													
Oligoneuriidae													
Coloburiscoides spp.	56	139										10	
Siphlonuridae													
Tasmanophlebia lacuscoerulei Tillyard	35	7		1									
Leptophlebiidae													
Atalophlebioides sp. 1	72	12		1									1
sp. 2	1	3											
A. pusillum (Harker)	31	64	3										
Atalophlebioides sp. 4	197	75		1							27		
Atalonella sp. 2	1098	1138	10	15					21	3	15	1	
sp. 3	1												
sp. 4	498	208	22	1			7						
Atalophlebia (nr.) longicaudata	15	55	3								2		
sp. 2	3												
A. australis (Walker)				4	6		1			1			
Atalophlebia sp. 4	45	207	13	4	2			1		14	194	2	
sp. 6	1			1									
sp. 7										1	9		
sp. 9	2	2	1	5	1								
Jappa sp. 1	156	6	1	1									
sp. 3	6											10	
Leptophlebiidae immature	570	307	30	49	4	5	3		20	29	108	10	3
Caenidae													
Tasmanocoenis tonnoiri Lestage (sp. 1)	397	17	12	43	36	103	115	1022	763	12350	4959	19006	
Tasmanocoenis sp. 3											22		
Baetidae													
Baetis sp. 1	7	1											
sp. 2	4	1											
sp. 3	5	1						1					
sp. 4	407	209	6	2				1	53				

Table 1B (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
sp. 5	20	89	1	2		7	6	92	90	763		11	
sp. 6	48	205	2	2		4	5	6				1	
<u>Cloeon</u> sp. 1										7	2		
<u>Centroptilum</u> sp. 1		2								1	12		
Baetidae immature	107	152	9	6	1	9	6	58	141	859	1	4	
ODONATA													
Aeshnidae													
<u>Austroaeshna</u> sp. 3	1	1								1			
Aeshnidae immature	1	1								1			
Gomphidae													
<u>Austrogomphus guerini</u> (Rambur)		1								2	1		
Gomphidae immature		1	1								1		
Synthemidae sp. 1		1											
Corduliidae immature										1			
Coenagrionidae													
<u>Ischnura heterosticta</u> (Burmeister)		1	12			1			2	4			
Coenagrionidae immature		1											
Chlorolestidae sp. 1			1										
sp. 2			1										
Megapodagrionidae sp. 1		1											
Protoneuridae sp. 1			4						1	13			
Amphipterygidae													
<u>Diphlebia</u> sp. 2											1		
Odonata immature										1			
PLECOPTERA													
Notonemouridae													
<u>Austrocercella mariannae</u> Illies	3												
Austroperlidae													
<u>Acruroperla atra</u> Samal	16	1	1										
<u>Austropentura victoria</u> Illies	3	3											
<u>Austroheptura picta</u> (Riek)	2												
Austroperlidae immature	1	1											
Gripopterygidae													
<u>Illiesoperla australis</u> Tillyard	4	3	1										
<u>Trinotoperla irrorata</u> Tillyard	10												
<u>T. nivata</u> Kimmins												20	
<u>Newmanoperla thoreyi</u> McLellan	28	69				1	1		2	4			
<u>Leptoperla neboissi</u> McLellan	24	19					1	1	2	40			
<u>L. primitiva</u> McLellan	14	43	30	3			10	17	15	70	12	3	
<u>Riekoperla tuberculata</u> McLellan	3	33											
<u>Dinotoperla christinae</u> McLellan	2	1											
<u>D. serricauda</u> Kimmins												20	
<u>D. brevipennis</u> Kimmins	30	31					1		6				
Gripopterygidae immature	75	121	22	4		4	6	15	17	359	15	26	
Plectoptera immature					1								
HEMIPTERA													
Veliidae													
<u>Microvelia oceanica</u> Distant										2			
<u>M. distincta</u> Malipatil										1			
Veliidae immature							1						
Mesoveliidae													
<u>Mesovelia hungerfordi</u> Hale									2				
Corixidae													
<u>Micronecta batilla</u> Hale	4	2		4	1		1	12	15	41		2	
Corixidae immature	6		34	14	2	28	55	242	266	224	26	77	2

Table 1B (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
MEGALOPTERA													
Corydalidae													
Archichauliodes sp. 2	2												
COLEOPTERA													
Dytiscidae													
Sternopriscus mundanus Clark (A)	1												
Antiporous femoralis (Boheman) (A)		2		1									
Carabhydrous niger Watts (A)	12												
sp. 2 (A)	1												
Allodessus bistrigatus (Clark) (A)		1											
Lancestes (nr.) *lanceolatus*	1												
Sternopriscus sp. 1	4		1										
Antiporous sp. 1										1			
Dytiscidae immature	2												
Gyrinidae													
Macrogyrus oblongus apacior Blackburn (A)			1	1									
Gyrinidae immature										1			
Hydraenidae													
Ochthebius sp. 1 (A)										1			
Hydraenidae sp. 1										1			
Hydrochidae unidentified (A)					1								
Hydrophilidae													
Hydrobius sp. 1 (A)									1				
Berosus sp. 1									1				
Helodidae													
Cyphon sp. 1	244	16		1					3				1
Cyphon sp. 1 (A)	1												
Psephenidae													
Sclerocyphon striatus Lea	4												
S. basicollis Lea			2										
Ptilodactylidae													
Byrrocryptus sp. 1	2												
Elmidae													
Kingolus sp. L1E	25	5											
sp. L5E	10		2										1
sp. L52E												11	
nr sp. L52E												6	
sp. L58E	1		1										
Simsonia sp. L3E									1				
S. hopsoni Cart. & Zeck			6								14	11	
S. tasmanica Blackburn		1	12						1				
Notriolus maculatus Cart.	18	18	2					2	7	10			1
N. quadraplagiatus Cart.	48	24	31	1				2	2	5		11	2
N. victoriae Cart. & Zeck		2	3										
N. allynensis Cart.	2	2	1						2				11
Notriolus immature	14	26	7		1		4			2	10	11	
Austrolimnius sp. L10E	224	70	2			1			2	1	71		
sp. L25E	911	240	50		2			1	3	2	135	47	1
sp. L34E											10	10	
sp. L58E	113	38	8		1		1		6		13		
sp. L62E											92		
sp. L64E	1	3									62		
sp. L65E	3												
Austrolimnius immature	20	1									45		

Table 1B (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Coxelmis novemnotata King	1		21				2		3	5			
C. v-fasciata Lea	1		1							11			
C. trinotata Cart. & Zeck			2										
Coxelmis immature											1		
Genus A sp. L15E	8	23			1								
Elmidae immature	1	1									11		10
Kingolus cupreus Cart. (A)												40	
K. metallicus King (A)	30												
K. yarrensis Cart. & Zeck (A)			1										
Kingolus unidentified (A)		5											
Simsonia hopsoni (A)											10		
sp. 1 (A)								1					
Simsonia unidentified (A)	2		1										
Notriolus maculatus (A)	1		1										
N. quadraplagiatus (A)	27	3	3						1				
N. victoriae (A)			1								1		
Austrolimnius sp. L39E (A)		1											
sp. 3 (A)	56	9	2							2	11	20	
sp. 5 (A)	15	2								10			
sp. 6 (A)	33	1									7	10	
Austrolimnius unidentified (A)												10	
Coxelmis novemnotata (A)										1			
C. trinotata (A)			1										
C. v-fasciata (A)			1										
DIPTERA													
Tipulidae sp. 1	193	124	5	1			2				4		
sp. 3	14	91	4		1	1			2				
sp. 5	28	42	8			9	1	1	62	4	1	10	
sp. 10	9	15			1		1	1	4				
sp. 17	13	32											
sp. 24	36	23	1		1	1							
sp. 27		7	2									10	
sp. 29	127	3	6				1						
sp. 32			1										
sp. 39	15												
sp. 45	10	2			1	1			1				
sp. 47	11	2							1	1		1	
sp. 49	2		1										
Tipulidae immature	63	69			1		1						
Psychodidae sp. 1		2						1					
sp. 2					1								
sp. 3	4	7	4		4	1	1						
sp. 4	3	1	1					1					
sp. 6			1										
sp. 7			2										
Chironomidae													
(Orthocladiinae)													
?Rheocricotopus sp. 1	68	95	7	24	7	14	1	1	3	5	22	74	
nr. Eukiefferiella sp. 1		8			66			1			10		
sp. 2						11			1				
Eukiefferiella sp. 1	849	506	130	902	181	239	220	279	196	1199	1148	699	
Thienemaniella sp. 1	900	1627	80	98	25	42	27	5	24	8			
Cricotopus sp. 1	989	336	92	1893	377	475	122	82	331	139	159	274	1
Corynoneura sp. 1	108	155	10	21	2		2		2	3			
sp. 2				1									
Psectrocladius sp. 1	26	94	15	38	17	42	47	20	6	579	174	28	

Table 1B (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
nr. Eurycnemus sp. 1	1	2	1		1								
nr. Cordites sp. 1	2461	6210	105	7		3	6		1		1		
Orthocladiinae sp. 39E		1			6				1				
sp. 103E		27	9	49	55	48	1	3	28			201	3
sp. 117E	1				2								
sp. 142E		32	8	2	3	9	13	2	3	8			
sp. 154E	1	7	1			2	2		1		50	2	
sp. 155E				45							10		
sp. 156E		1											
(Chironomini)													
Dictrotendipes sp. 2				6		3		6		1	1	26	
Riethia sp. 1	2216	264	43	581	88	113	20	46	23	10	606	43	
Cryptochironomus grisiedorsum (Kieffer)	57	391	146	596	162	156	105	97	106	20	128	16	1
nr. Saetheria sp. 1	21	18				82	22	15	1	3			
Polypedilum sp. 1	6883	4314	1442	234	274	615	1688	459	813	159	1447	339	1
sp. 6	3	27	43	8	14	87	1939	427	1037	14	911	14	4
Harnischia gp sp. 1	24	6									10		
gp sp. 2	1785	1009	101	228	7	34	34	40	42	194	7	112	
Skusella sp. 1	29	1							1				
?Xenochironomus sp. 1	10			1									
Kiefferulus martini Freeman		1	1		1	4							
Chironomus cloacalis Atchely & Martin		1									2		
?Chironomus sp. 2						1				40			
Chironomus sp. 4	20	78	1035	15	33	213	209	87	640	16	167		
Parachironomus sp. 1			1	17	18	62		4	16	2681			
?Parachironomus sp. 3	373	92	1	2						1		4	
Paraborniella sp. 1	39	50	9	1	1	5					1		
?Microchironomus sp. 1	11	2	342	21	17	84	114	110	258	6	1	20	
Chironomini sp. 3E	5	4	1		3	1					2		
sp. 34E		2											
sp. 148E	3		1										
(Tanytarsini)													
Rheotanytarsus sp. 1	219	683	89	846	69	288	19	90	106	380	130	1159	10
?Calopsectra sp. 1	11993	4590	411	489	159	268	173	125	184	124	7882	4772	
Micropsectra sp. 1	218	142	14	118	7	13		5	4	23	224	57	
Stempellina nr. bausei sp. 1	3975	162	13		1		1	1	1	1			
Tanytarsini sp. 122E		15	3	2139	29	193	43	401	562	49	2979	122	
(Tanypodinae)													
Ablabesmyia sp. 1	18	9	2	2				10	1	1002	64		
Macropelopia sp. 1	21		1										
Pentaneura sp. 1	1277	488	40	376	39	22	3	3	5	48	12	1	
Procladius sp. 1	727	70	154	39	33	105	147	27	170	47	1912	234	
Coelopymia pruinosa Freeman	3	5	22	2	4	7	9	6	8	10	211	43	
Tanypodinae sp. 108E	8	8											
sp. LTCS15											21	31	
Aphroteniinae sp. 18E	56	46	2								2	11	
(Podonominae)													
Podonomopsis sp. 1		1							3	1			
Podonomus sp. 1	73	21	1	2	21								
Chironomidae pupae	31	14	6	1	1	4	11	2	13	12	2		
Chironomidae immature	93	38	77	57	10	77	27	30	135	37	450	94	
Ceratopogonidae													
Dasyhelea sp. 1	177	89	1										
sp. 2				1	1	1	1			2			
Nilobezzia sp. 1	204	418	14	2		4			2	1	1	1	
Alludomyia sp. 1	1												
nr. Atrichopogon sp. 1	1												

Table 1B (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Bezzia sp. 1	360	9	7				3		1	2	4		
nr. *Forcipomyia* sp. 1									1	2			
Ceratopogonidae sp. 13		2	2			2			5	2			
sp. 15	1219	311	14		1	1	1		4	3	10	1	
Simuliidae													
Austrosimulium montanum Mackerras & Mackerras		2								3			
A. victoriae Rouband	4	33								12			
A. furiosum Skuse	2	22						2	1	27			
Simulium ornatipes Skuse	25	14				1			1	6			
Simuliidae imature	17	14	2			2	4	4	3	40	1	10	
Blephariceridae													
Edwardsina polymorpha Zwick		4											
Athericidae sp. 1			1										
Tabanidae sp. 1		1						1	1				
Stratiomyidae sp. 3		1					1						
Empididae sp. 2	3	1	1										
sp. 3	115	312	39	15		8	2		4	9	192	127	
sp. 9				1		1							
Dolichopodidae sp. 1		3	1				1		1				
Ephydridae sp. 1		4	2					2					
Muscidae sp. 1	1												
TRICHOPTERA													
Hydrobiosidae													
Ethochorema sp. 1		4											
Ethochorema gp (sp. 4)	26	52		1						1			
Apsilochorema obliquum Mosely		1											
Ulmerochorema gp sp. 2		1											
U. onychion Neboiss	1	17											
Tanjilana sp. 1	37												
Hydrobiosidae immature	27	21	1		1								
Glossosomatidae													
Agapetus sp. 1				22									
Glossosomatidae immature	1	1											
Hydroptilidae													
Hydroptila sp. 1										1			
sp. 2							1						
H. (?scamanda)			2			1						23	
Orthotrichia atraseta Wells	3									1			
Hellyethira (?simplex)				1		1							
sp. 1		3	7			1			2		104	30	
sp. 2													
Oxyethira columba (Neboiss)		1									1	1	
Hydroptilidae sp. 5	12	2											
Hydroptilidae immature	3	3			1	3			1	6	80	13	
Philopotamidae													
Hydrobiosella sp. 1	10												
Chimarra sp. 1			2										
Ecnomidae													
?*Ecnomina* sp. 1	785	4						1			2		
sp. 2	2												
sp. 3	4	1											
sp. 4	69	40											
Ecnomus sp. 1	2		1										
Ecnomus spp.	1	5	40	2251	658	1281	283	1402	331	88	429	8	
Ecnomidae immature	2		2				1						

Table 1B (continued).

	sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Polycentropodidae sp. 4			1										
Hydropsychidae													
Smicrophylax sp. 1		1											
Asmicridea edwardsi (McLachlan)	1	14	3			2	7	30	24	10			1
Cheumatopsyche sp. 1	107	39	3		22	28	28	54	32	8		16	
sp. 2	26				2	2		1	1				
sp. 3			1	1									
sp. 4	20	13	8										
Hydropsychidae immature		2			1	33			2	3	3		
Kokiriidae													
Tanjistomella verna Neboiss	31	28	1	1									
Conoesucidae													
Conoesucus sp. 1	1	6											
Costora delora Mosely	18	3		1									
Conoesucidae sp. 6	1												
sp. 8		1											
sp. 9	3	1			1							11	
sp. 10	2										1		
Conoesucidae immature													
Calocidae													
Tamasia variegata Mosely	24												
Calamoceratidae													
Anisocentropus sp. 1	1										2		
Philorheithridae sp. 1	16	10											
sp. 2	20	2	2										
sp. 4	11												
sp. 6	2												
sp. 7	49												
sp. 9	14												
Philorheithridae immature	4	3											
Leptoceridae													
Notalina bifaria Neboiss	366	198		4			1	1	2				
N. fulva Kimmins (Type A)		3	2		1	1			1	4	1	3	
N. fulva Kimmins (Type B)	444	11					2				1		
?*Triaenodes* sp. 1		2											
Triplectides sp. 1	4	23	8						2	3			
sp. 2	19	11	24			6	2	2		29	2		1
Triplectides sp. 3	1	2	4				1			17			
T. (?*proximus*)		1											
Oecetis sp. 1	5	10	1	2			1	3		60	2		1
sp. 2		1	4		3	1		4	3	3			
sp. 3	1												
Leptoceridae sp. 23E		3											
Leptoceridae immature	143	13	6	4			2	2	6	14	87	10	2
Atriplectidae													
Atriplectes dubia Mosely	23	1	10										
Trichoptera pupae								1					
Trichoptera immature							1		2				

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Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria, to the construction and operation of Dartmouth Dam. 1. Construction and initial filling period.

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Abstract. Blyth, J.D., Doeg, T.J., and St Clair, R.M. (1984) Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria, to the construction and operation of Dartmouth Dam: 1. Construction and initial filling period. *Occ. Pap. Mus. Vict.* 1:83–100.

The benthic macroinvertebrate communities of the Mitta Mitta River were sampled during the construction and first few years of the impoundment of the Dartmouth Dam (1974–1979). The study period was marked by a series of acute and chronic impacts on the fauna, leading to a change, upstream of Snowy Creek, from a diverse fauna with a few taxa from headwaters and lowlands, and a large component of foothill taxa, to a comparatively depauperate fauna numerically dominated by a few tolerant, widespread taxa. The most significant chronic impact was a large increase in the sediment bed load caused by construction activities, producing severe reductions in the headwater and foothills species and large increases in the number of individuals of Oligochaeta and some Chironomidae at all sites. Dam closure resulted in the loss of many individuals, from all taxa, due to exposure, premature emergence and catastrophic drift. The period of filling, marked by low, constant release, depressed summer and elevated winter temperatures, and periods of poor water quality, further eliminated many species not adapted to these new regimes. The impact during filling decreased with increasing distance from the dam, with the lowest site (50 km downstream) being relatively unaffected by the post-impoundment conditions. Some recovery was noted at a site immediately downstream of a major tributary, but this was not sustained further downstream.

Introduction

Dartmouth Dam, impounding 4×10^6 Ml at full supply level, is located on the Mitta Mitta River in the northeastern highlands of Victoria. It is the deepest reservoir yet constructed in Australia (66 m) and, with a total surface area of 63 km^2, extends some 40 km along the Mitta Mitta River. Full details of the design and construction of the dam are given by State Rivers and Water Supply Commission (1978). The major function of the reservoir is to provide emergency irrigation support to Lake Hume and the Murray Valley during extended drought periods. It is also used for base load hydroelectric generation.

Major construction activities began in mid-1972 with the building of an access road from Mitta Mitta to a new township, Dartmouth, situated a few kilometres below the dam site. Work on the diversion tunnel and dam wall began in mid-1973 and continued until 1977 when the diversion outlet was closed and filling began. A pondage weir was constructed near Dartmouth in 1978.

Filling continued until late 1980 when the first major operational release of 8000 Ml/day for three months was made.

The Dartmouth Environmental Studies were initiated by the River Murray Commission and the State Rivers and Water Supply Commission (SRWSC), to investigate the impact of the construction and operation of the dam on the local environment, with a view to developing future management programmes. The National Museum of Victoria (NMV) (now part of the Museum of Victoria) was commissioned to study the invertebrate fauna of the catchment area. Results of the baseline study were reported by Smith et al., (1977, 1978). This report deals specifically with the effect of the construction and filling periods (1972– 1980) on the benthic macroinvertebrate communities in the Mitta Mitta River downstream of the dam site. The impact of the irrigation release is covered in a separate paper (Doeg, 1984).

Procedures and methods

The study area

The study area (Fig. 1) covers the Mitta Mitta River below the wall of the Dartmouth Dam to Tallandoon, about 50 km downstream. This includes two distinct

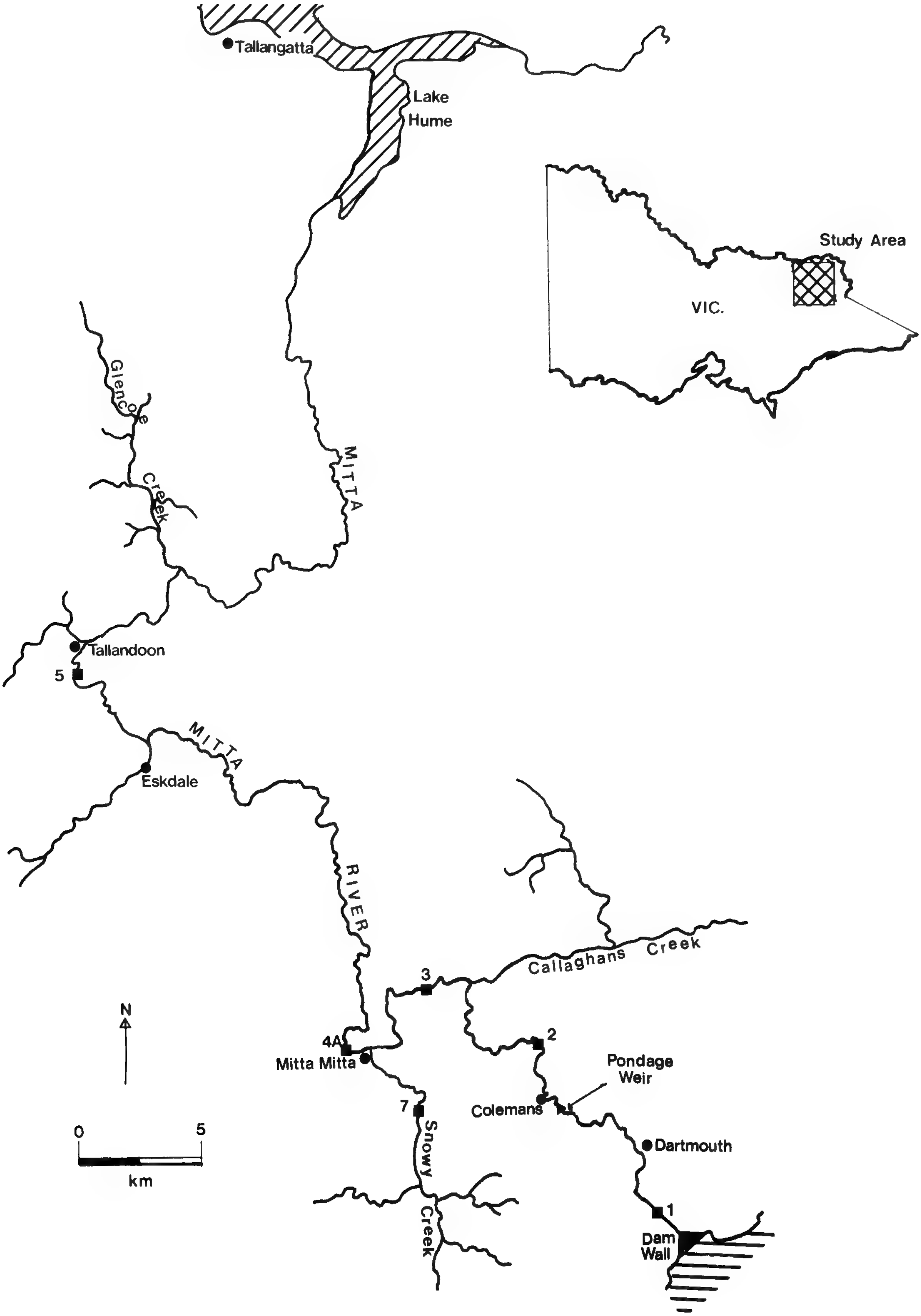

Fig. 1. The study area, showing the location of sampling sites.

zones of river morphology. For most of the distance between the dam and the Snowy Creek confluence, the river flows through typical upland and foothills habitat (average gradient of 4.4%) with steep granitic valleys, dominated by stands of dry eucalypt forest. Prior to the construction of the dam, the river consisted of rapids and deep pools flowing over a bed largely composed of rocky outcrops, boulders and cobbles.

Near Mitta Mitta township, the river flows out of the foothills into a wide valley (average gradient of 0.7%) which has been extensively cleared for agriculture since the late 1880s (SRWSC, 1978). The river here is wider and slower than the upstream section and meanders over the floor of the valley. The bed is mainly composed of smaller particles (cobbles to sand) with extensive rubble banks along some sections. Stands of *E. camaldulensis* (redgum) and *Salix* spp. (willows) occur along the mainly cleared banks.

Hereafter, these two distinct zones shall be referred to as the 'foothills' area and the 'lowland' area.

Collecting sites

Six main sampling sites were selected, five on the Mitta Mitta River and one (site 7) on Snowy Creek, the major tributary. Three sites (1, 2, 3) were in the foothill section of the study area, site 4A was just below the confluence of Snowy Creek and site 5 was located near Tallandoon in the lowland area. Descriptions of each site are given in Appendix 1. The dominant substratum materials were cobbles, pebbles and gravel, with varying small amounts of sand. Another control site was selected on the Mitta Mitta River, above full supply level of the reservoir. This site, C3, was about 50 km upstream of the dam wall and was sampled in the last three trips only.

Collecting trips

Between February 1974 and February 1979, eleven major sampling trips were made. During construction, collections were made in February 1974, February 1975, November 1976 and March 1977. Samples were taken in November 1977 just prior to, and 2 weeks after, the closure of the diversion outlet. During the filling period collections were made in February 1978, July 1978, October 1978 and February 1979.

Collecting methods

Due to changes in staff, constraints of time, and physical changes in the river over the study period, there have been inconsistencies in the sampling methods employed. Two distinct techniques (Surber and kick sampling) were used involving two different mesh sizes: in 1974 and 1976, Surber samples with a mesh size of 250 and 160 μm respectively, and since March 1977, kick samples with 160 μm mesh have been used exclusively. As all methods sampled essentially the same component of the fauna but in differing absolute numbers, only qualitative results will be presented here. Despite these shortcomings, it is still possible to present a detailed picture of the overall faunal changes in the river.

At each site, a series of samples was taken in both fast water (defined as having a current of over 70 cm sec^{-1}) and slow water or pools (under 40 cm sec^{-1}), although more emphasis was placed on sorting and identifying animals from the fast water samples. Collected material was preserved in 10% formalin solution and a counterstaining technique, described by Williams and Williams (1974), was used to contrast animals against silt and algae. Lugol's iodine or Rose Bengal were used to stain the animals and Chlorazol Black E was used to darken the silt and algae.

Drift fauna was collected in square frame nets with a mouth size of 31 x 31 cm and a mesh of 135 μm. The nets were placed firmly on the bottom of the river and were emptied hourly for 4 or 5 hours, beginning one hour before sunset. They were cleared at varying intervals over the rest of the day. Intensive drift netting was carried out during dam closure (2 Nov 1977 to 16 Nov 1977).

Sorting and identification of specimens

In the laboratory, organic and inorganic material were separated by elutriation. The inorganic fraction, after careful checking for molluscs and cased animals, was discarded. Prior to 1977, animals were selected from the entire organic fraction under a stereomicroscope. Subsequently, the organic fraction was subsampled to 1/10th of its original volume and only animals in the subsample were sorted.

Where possible, specimens have been identified to species using the reference collection and literature of the Museum of Victoria. Where groups could not be identified in this manner, presumptive species were allocated code numbers in line with a voucher system being developed by the Biological Survey Department of the NMV.

Physicochemical results

Discharge

Mean monthly discharge (in Ml day^{-1}) for three sites on the Mitta Mitta River and Snowy Creek are given in Figure 2. Gauging stations at Tallandoon and Snowy Creek are close to sites 5 and 7 respectively and Colemans station is 5 km upstream of site 2. Thus, records are presented for the foothill and lowland zones and for Snowy Creek from 1967 to April 1981. This represents a five year preconstruction period (1967–1972), five years of construction (1972–1977) and four years of filling and operation.

For all three sites the pre-construction and construction periods were marked by natural seasonal variation in discharge with maxima in late winter and spring, and minima in late summer and autumn.

At dam closure, on November 3 1977, a dramatic reduction in discharge was noted over a 24 hour period at both Colemans (from 619 to 21 Ml day^{-1}) and Tallandoon (1424 to 602 Ml day^{-1}). No such decrease occurred in Snowy Creek (208 to 192 Ml day^{-1}).

The discharge at Colemans over the three years following dam closure was essentially constant at around 200 Ml day^{-1}, with virtually no seasonal variation. On several occasions, 3–16 November 1977, 5–12 July 1978, 24 July – 29 August 1978 and 14 September – 14 November 1978, actual release from the dam was zero and flow in the river became totally dependent on seepage and inflows from tributary streams. At these times, discharge rates near the dam occasionally fell to below 1 Ml day^{-1} (SRWSC, unpublished data).

Over the same period, the discharge pattern at Snowy Creek remained unaffected.

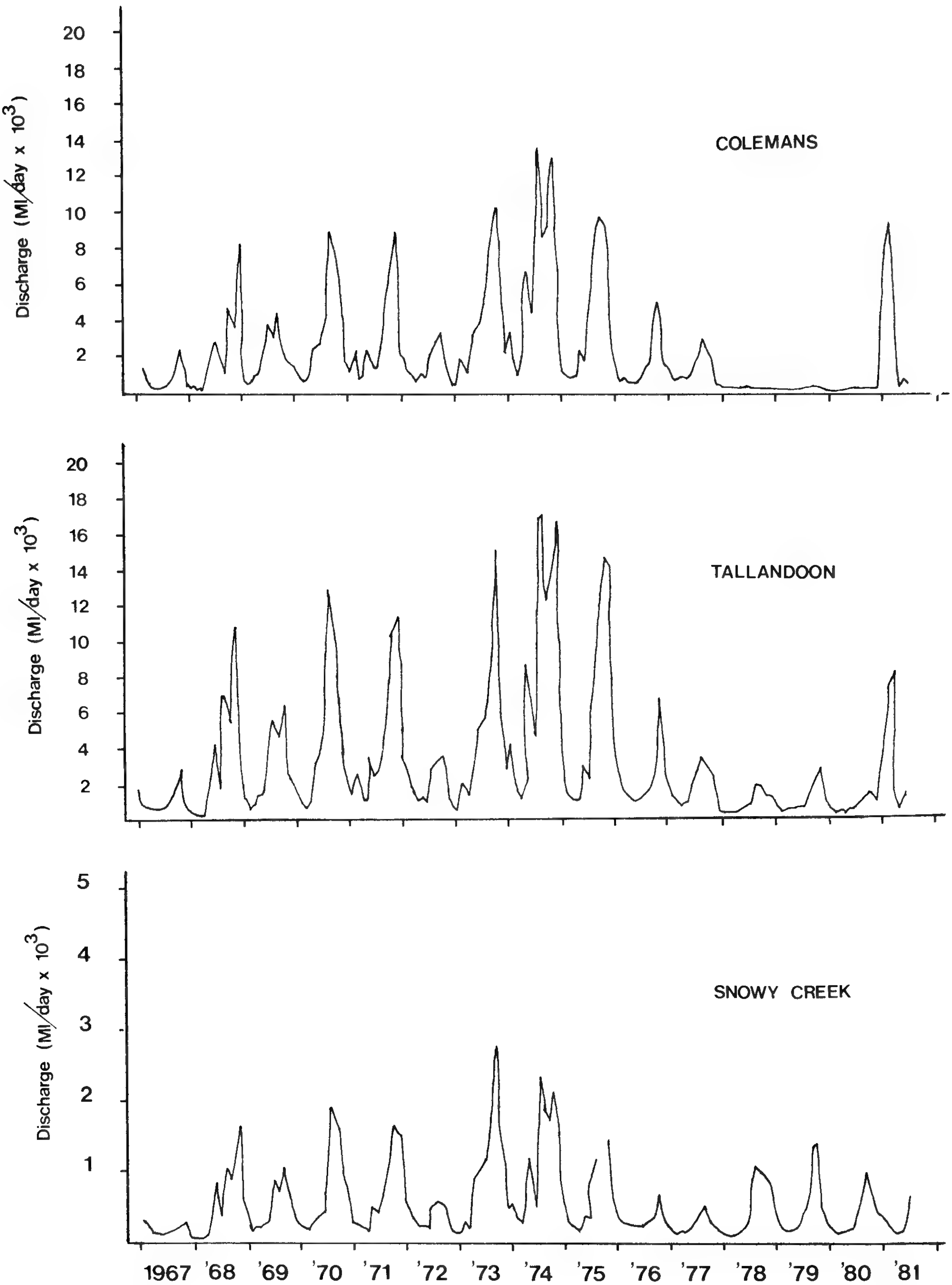

Fig. 2. Mean monthly discharge (in Ml day^{-1}) at three gauging stations in the study area (SRWSC, unpublished data.)

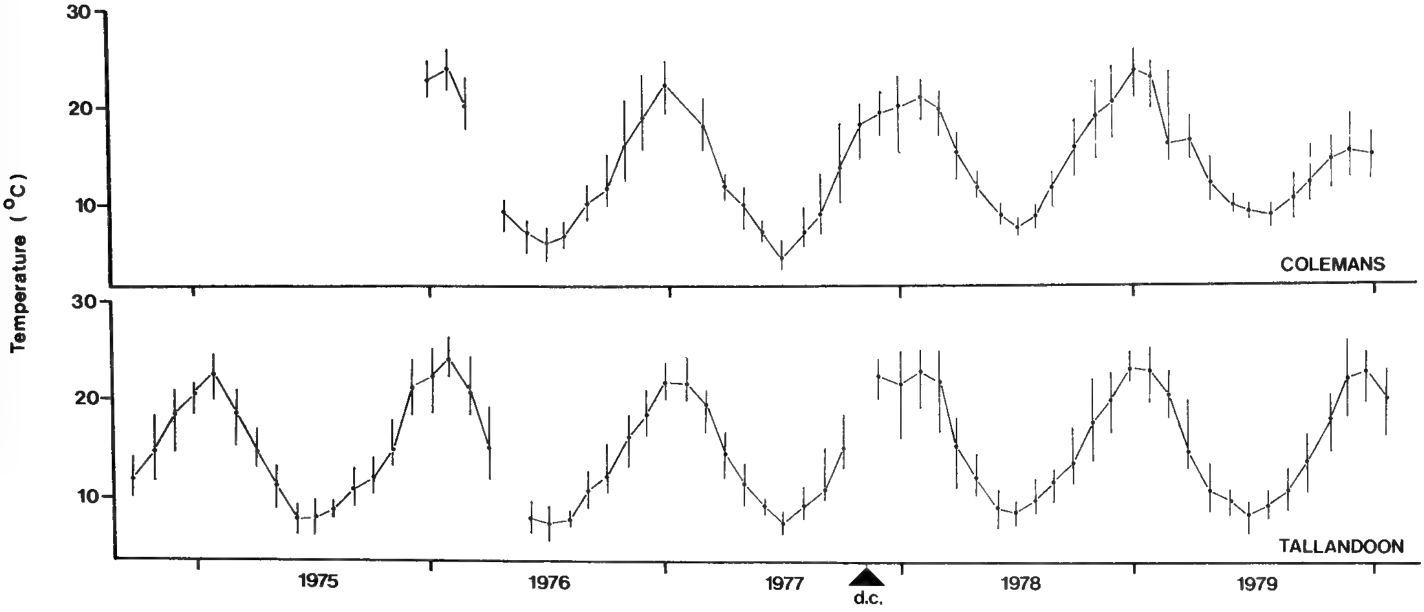

Fig. 3. Mean monthly water temperature and range at two guaging stations in the study area (SEC, unpublished data).

The discharge patterns at Tallandoon following dam closure still showed distinct seasonal variation, although the amplitude is comparable to extremely dry years prior to dam closure (e.g., 1967, 1972). This maintenance of seasonal flow regimes was due to inflows from several unregulated tributaries. Snowy Creek contributed over 50% of the peak winter flows at Tallandoon (compared with under 20% before dam closure).

The irrigation release can be identified as a distinct peak in the summer of 1980/81 at both stations on the Mitta Mitta River.

Temperature

The monthly mean and range of temperatures recorded at Colemans and Tallandoon gauging stations for the period 1975 to 1980 are shown in Fig. 3.

During the first year of filling (1978), when release was via the low level outlet, summer temperatures at Colemans appeared to be slightly depressed (compared to 1976 and 1977 levels) and the winter temperatures were elevated by about 5°C. Discharge was transferred to the high level outlet in October 1978, and with the release of surface water, summer temperatures were higher then preclosure levels and winter temperatures remained elevated. As the water level in the dam rose well over the outlet tower, release became hypolimnetic late in 1979 and a severe depression (by 8–10°C) in the temperature of the release water was noted over the following summer.

However at Tallandoon, the temperature of the release water was relatively unimportant, with low discharges, the input from Snowy Creek, and the uptake of heat from the atmosphere permitting a return to the pre-impoundment temperature regime.

Figure 4 shows the daily mean and range of temperatures recorded in November 1977 at Dartmouth township, covering the period of dam closure. Also included is the daily discharge at the same station showing the rapid decline at dam closure (3 November) and the extremely low flow during the initial no- release period. During the two weeks following closure, water temperature rose sharply, with large daily fluctuations. With the introduction of riparian release (16 November), temperatures initially fell below preclosure levels but rose back to them by the end of the month, while retaining the large daily variations.

Other physical and chemical factors

Pre-impoundment water quality was described by Graham et al., (1978). The following description of river water quality during the impoundment period is based upon unpublished SRWSC data, collected as part of a comprehensive survey of Victorian aquatic systems.

During the first year of impoundment, water was released from the low level outlet. Due to the decomposition of organic material inundated by the reservoir, the water quality rapidly deteriorated with low dissolved oxygen levels (at times less than 10% saturation) and the production of high levels of iron, manganese and hydrogen sulphide. Electrical conductivity, total dissolved solids, hardness, sulphate, magnesium, phosphorus, nitrate and nitrite, potassium and total organic carbon in the release water were all higher than preimpoundment maxima at Dartmouth, although improvement in many recordings were noted in the first 10 km downstream of the dam.

By Tallandoon, with the input of tributary waters, all parameters measured had returned to within the range of pre- impoundment values.

The release of surface water from the highest outlets in late 1978 resulted in marked improvement in water quality, but this was only sustained until discharge became hypolimnetic in 1979, when a decrease in quality was again observed.

Field observations

During the construction period, direct observation showed that increases in the sediment bed load constituted a major physical change to the river. By 1976, two distinct facets of bed sedimentation were recorded; the deposition of large quantities of fine sediment in pools and along banks where the current was slow, (Fig. 5) and the formation of a thick silt and algal carpet covering most of the vertical and horizontal surfaces in riffle and rapid

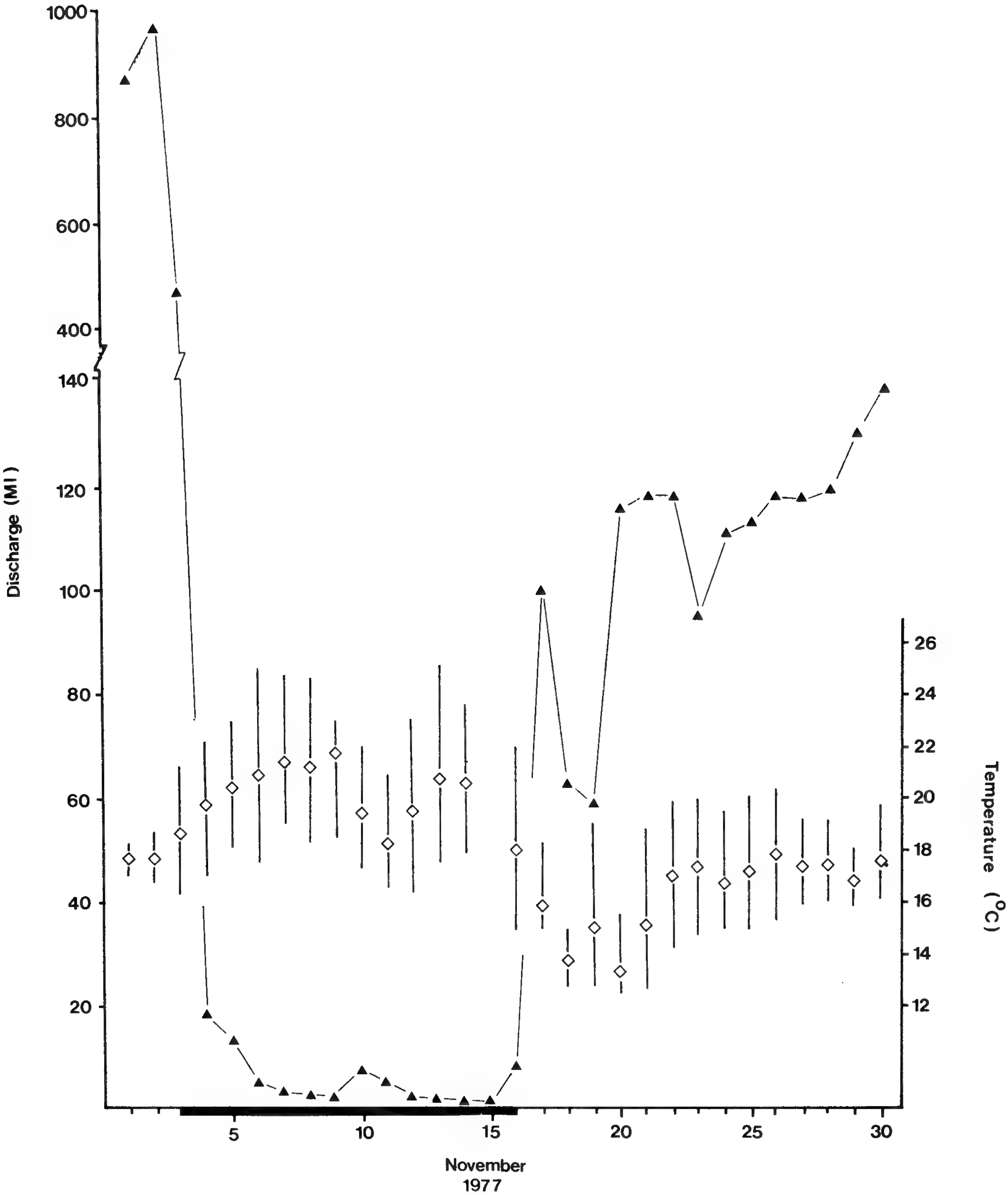

Fig. 4. Daily discharge and mean water temperature and range at Dartmouth gauging station for November 1977. Dam closure was on 3 November and the black bar indicates the initial no-release period.

areas (Fig. 6). The silt/algal matrix was particularly heavy at sites 1, 2 and 3 forming a cover of between 1 and 10 mm over all surfaces. Further downstream the carpet became increasingly patchy and less stable, and by Tallandoon the deposit contained less sediment and more filamentous algae. Thus, the sedimentation followed the classical pattern of point source pollution, with a severe impact close to the dam and gradual recovery with increasing distance downstream.

The silt/algal matrix prevalent at sites 1, 2 and 3 consisted of sediment bound by algae, cyanobacteria (mainly motile species of the bluegreen genera *Lyngbya* and *Os-*

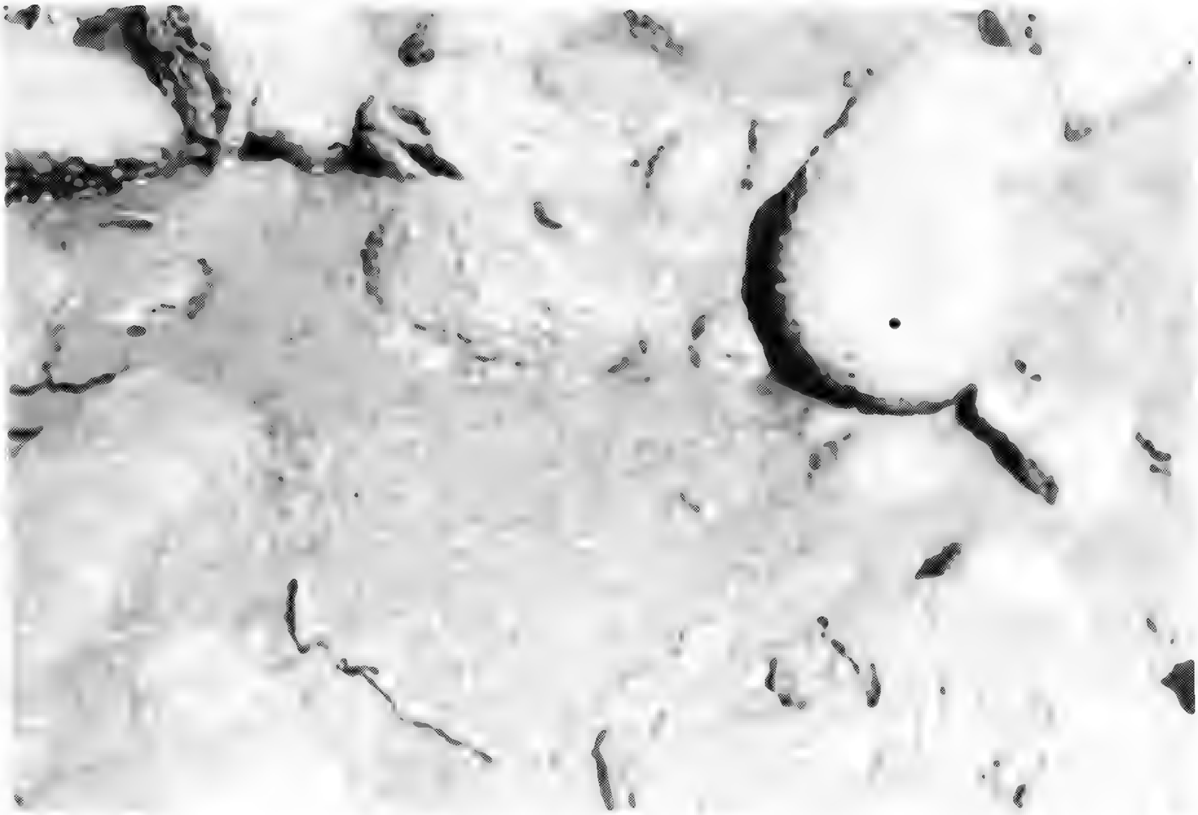

Fig. 5. Sediment in area of slow current, exposed during dam closure.

Fig. 6. Sediment/microbial mat on solid vertical surface, originally exposed to fast currents.

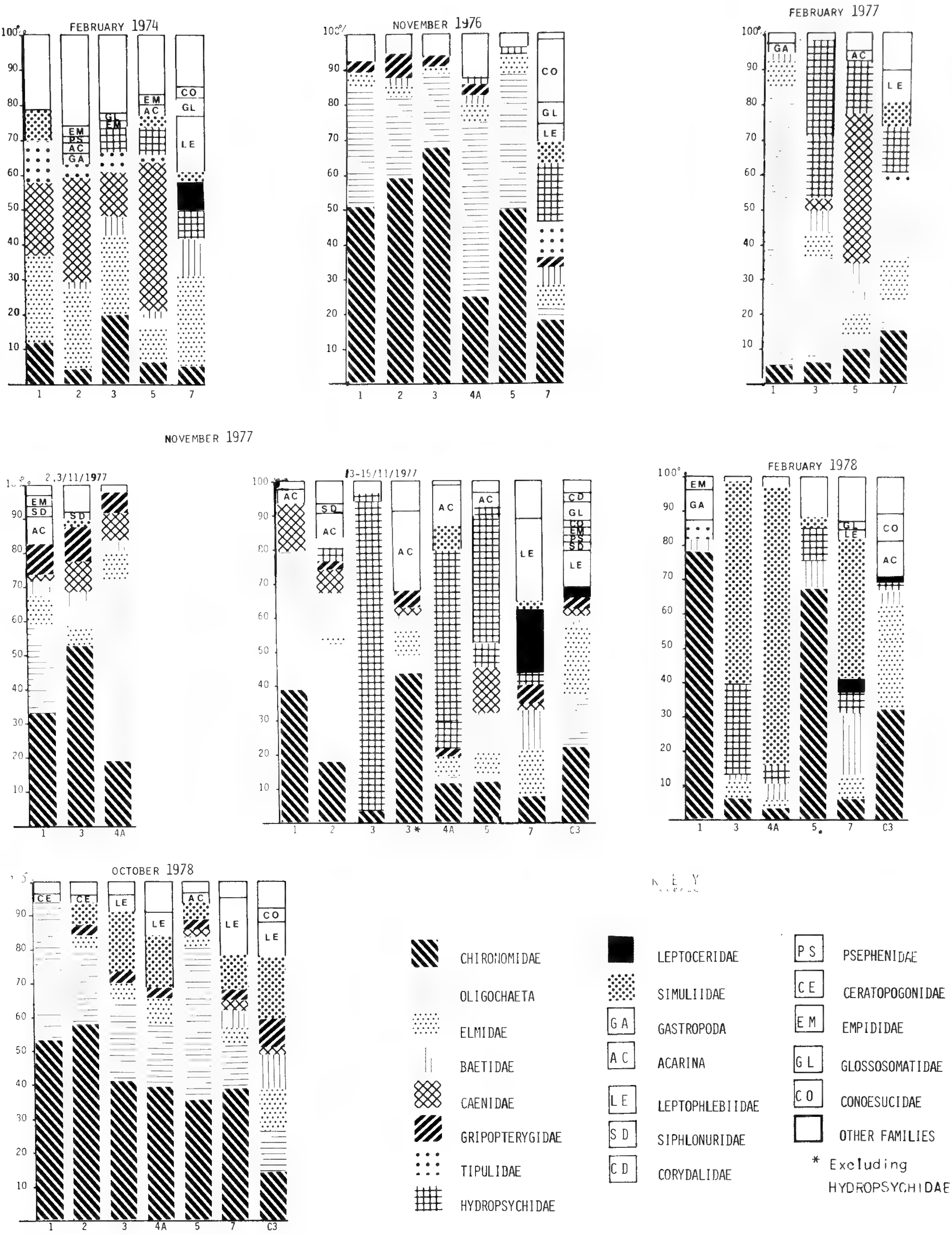

Fig. 7. Percentage abundance of various major taxa at each site for seven collections. Only taxa with over 2.5% of the total abundance are shown. Site C3 (November 1977 – October 1978) was located on the Mitta Mitta River, 50 km above the dam wall, near Omeo, Victoria.

cillatoria) with a distinctly layered structure, due to the alternation of plant matter and sediment particles. The diatom, *Melosira varians* and the green alga *Stigeoclonium* sp., were also common downstream of the dam site, and were the dominant algae at Tallandoon. Upstream of the dam site there was no obvious sedimentation and the common algae were the blue green genera, *Nostoc* and *Rivularia* plus an unidentified, mucilaginous green alga. The species abundant below the dam site were not observed at control sites.

The commencement of impoundment in November 1977 brought several dramatic changes to the nature of the river. With no discharge from the dam, the river dropped rapidly to become a series of slow flowing interconnecting pools throughout the 35 km stretch between the dam and the Snowy Creek confluence. A visual estimate indicated that approximately 60% of the riffle areas and 20% of the previous pool areas became exposed as the water level receded. The remaining riffles were much shallower and slower and the pools became almost still.

Many animals, trapped in small pools left behind by the receding water, were observed actively swimming on the surface. Individuals from many taxa were observed and it appeared that most of them perished, presumably due to the rapid heating, oxygen depletion and lack of current in the pools.

A few hours after dam closure, large numbers of animals were visible drifting in the reduced river channel. The first to appear, within minutes of the decreasing flow becoming apparent, were species adapted to fast currents, such as the Siphlonuridae and various Plecoptera, and those from edges and backwaters, such as some Leptoceridae.

On the first night of closure, faunal drift increased greatly, even compared to the elevated daytime drift rate, being particularly heavy in the first hours after sunset. All common taxa were observed in the drift.

Another rapid response to the cessation of flow was the emergence of large numbers of adult insects, many of which died during or immediately after eclosion. Large number of Chironomidae and Caenidae adults were seen in emergent swarms or washed up on the exposed substrata.

With the resumption of flow, the river level rose and the riffles and rapids became deeper and faster, although still much reduced in area and current compared to pre-impoundment periods. Habitats such as backwaters, very fast turbulent rapids and fast flowing pools were either lost entirely or greatly diminished. conditions downstream of Mitta Mitta township, due to the inflow of Snowy Creek, were not as greatly affected as upstream sites.

The heavy bed sedimentation observed during construction mostly remained at sites above Snowy Creek in the low flow of the filling period, although much of the algal/sediment complex at site 4A disappeared.

Faunal results

Fast water

Most analysis is of qualitative results from three main trips, concentration on the more common taxa. The three main collections used are February 1974, November 1976 and October 1978, representing faunal assemblages from baseline, construction and filling periods. Results from other trips (summarized in Fig. 7), are available from this laboratory and, although not as extensively sorted and identified, support the observations made from the three 'typical' collections.

Distribution of taxa. In 1974 the distribution of individuals amongst the higher taxa contributing at least 2% of total animals was relatively even (Fig. 7). At all sites, a large proportion of the fauna was composed of rare taxa, indicative of a diverse assemblage. By 1976, the fauna at sites on the Mitta Mitta River had become dominated by Chironomidae and Oligochaeta, which contributed over 75% of the total abundance at each site. Site 7, on Snowy Creek, had retained the faunal diversity observed in 1974. In October 1978, Chironomidae and Oligochaeta still formed over 50% of the fauna at the main river sites, although the dominance by these two taxa declined progressively between sites 1 and 4A, rising again at site 5. The two control sites, 7 and C3, again showed a pattern similar to that of all sites in 1974.

Looking in detail at the distribution of particular taxa, several different reactions to the impacts of construction and impoundment were observed (Appendix 2).

(i)The numerical dominance of the Chironomidae from 1976 onwards as due to only a few species belong to the genera *Cricotopus* (sp 12E), *Eukiefferiella* (sp 70E), *Cardiocladius* (sp 39E), *Paraheptagyia* (sp 23E) and Aphroteniinae (sp 18E).

(ii)Some taxa (e.g., many Elmidae, Psephenidae, Glossosomatidae) declined in numbers during construction and remained rare or undetected after closure. Some members of the Chironomidae (e.g., *Polypedilum* (sp 16E) and *Procladius* (sp 66E)) were amongst this group of adversely affected taxa.

(iii) Many species (e.g., Elmidae sp L10E, *Dinotoperla serricauda*) occurring in large numbers at virtually all sites, only declined in abundance over the study period at site 1.

(iv) Some species (e.g., *Trinotoperla nivata*) remained common during construction but declined during filling.

(v) Some taxa (e.g., Hydropsychidae) increased in abundance only during the filling period.

(vi) Some taxa (e.g., some Hydracarina) were only adversely effected at sites upstream of the Snow Creek confluence.

(vii) One species (Chironomidae sp 2E) remained common at the two most upstream sites during construction, but declined at downstream sites. This species declined at all sites during impoundment.

Overall, both species richness and evenness have declined at sites 1, 2 and 3 over the entire study period, and species lost have mainly been from the Ephemeroptera, Plecoptera, Elmidae, Trichoptera and Hydracarina. Diversity at site 5 declined, although not to the same extent as at upstream sites, during the construction period, but does not appear to have been further affected during the impoundment period.

The reasons for these different reactions to the changing conditions in the river, both by sites and individual taxa, are addressed in the discussion.

Community Composition. Figure 8 depicts dendrograms showing site relationships indicated by shared and unshared taxa (of different ranks) for the three 'main' collections using the Sorensen (1948) similarity coefficient and the flexible classificatory strategy (β -0.25), de-

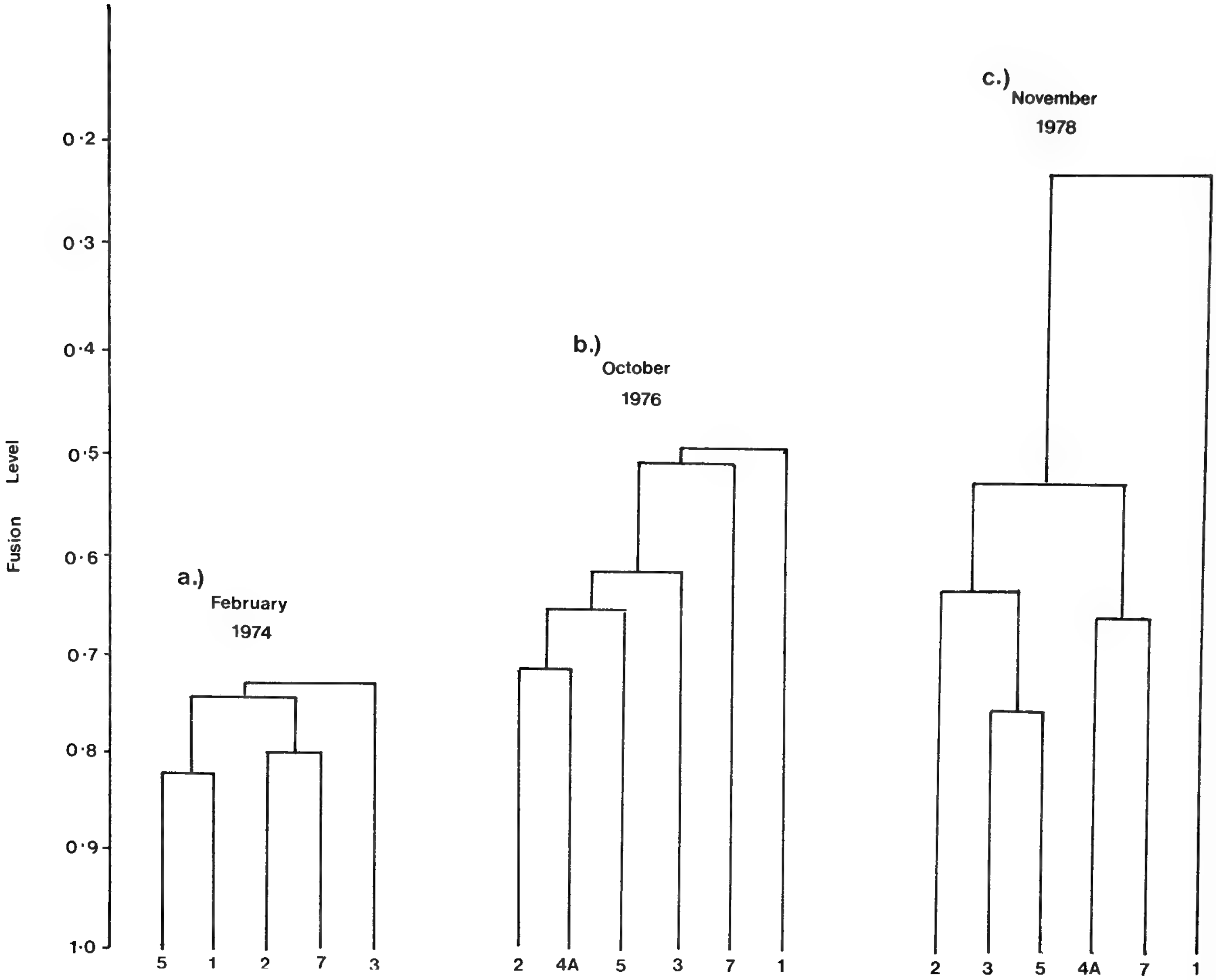

Fig. 8. Dendrograms showing site relationships for the three collections being used.

scribed by Lance and Williams (1967). These present a convenient summary of the changes throughout construction and impoundment. In 1974 (Fig.8a) all sites grouped together at a high similarity, indicating a close relationship between the faunal assemblages at all sites. By 1976 (Fig.8b) site 1 showed little similarity to the other sites and there was a clear separation of the Mitta Mitta River sites (2,3,4A, 5) and the Snowy Creek site (7). In 1978 (Fig.8c) site 1 remained distinct but site 4A had become closely associated with site 7. Sites 2, 3 and 5 retained the comparatively close affinity displayed in 1976.

Slow water

Although less emphasis was placed on sampling, sorting and identifying the fauna from pools and slow water, it was apparent that changes occurred which were not observed in fast water (Blyth, unpublished data). In 1974, the fauna of slow waters was essentially a less diverse version of that occurring in the riffle zones (Smith et al., 1978). This characteristic has been observed in several Victorian Rivers (e.g., Malipatil and Blyth, 1982). During construction, changes in the fauna were similar to those observed in fast water.

However, after dam closure, the very low discharge upstream of Snowy Creek reduced the suitability of pool reaches for lotic fauna, so that mainly still water forms such as Dytiscidae, Hydrophilidae and some Hydracarina, which did not proliferate in riffle zones, became abundant. Planktonic Crustacea also were very common in the almost stationary pools. As a result of these changes, pool and riffle communities became recognisably distinct during the impoundment period.

Due to the output of Snowy Creek, pool fauna in the lowland section of the study area was not as seriously affected, retaining many members of the typically lotic fauna.

Drift fauna

A detailed analysis of the drift samples taken during dam closure (November 1977) will be presented separately. The drift densities in the Mitta Mitta River were at least ten times greater after dam closure than before, both during the day and at night. Drift was particularly heavy in the first two or three hours after sunset so, despite the increase in drift rate, the natural diurnal pattern with peak numbers at night (Waters, 1972) was retained.

Discussion

Introduction

Much of our understanding of the effects that dams have on the benthic fauna of the receiving stream comes from work conducted overseas. Studies on the effects of reservoirs on Australian stream are rare, and mainly deal with the fish populations or physicochemical conditions in the river (e.g., Bishop and Bell, 1978; Walker, 1980). Little work has been done in this country on the macroinvertebrate communities in lotic sections of regulated streams, exceptions being Coleman (1979), Malipatil and Blyth (1982), the Dartmouth studies reported here,the work carried out on the Thomson River system by this laboratory, (Davey et al., 1982) and occasional unpublished theses.

Most of the overseas studies conclude that reservoirs have a deleterious effect on the riverine fauna by reducing species diversity and altering community composition (e.g., reviews by Ward, 1976; Ward and Stanford, 1979). There are several factors contributing to this change, the four most commonly cited being modifications to the historical pattern of temperature, flow, water quality and sediment load.

The disturbance of seasonal temperature patterns can lead to the disruption of various key events in the life cycles of macroinvertebrate species, such as egg hatching and the emergence of adults (Hynes, 1970). Ward and Stanford (1979) review the effects of thermal modification on receiving streams by dams. The extent to which impoundments alter the temperature regime of downstream sections depends largely on the operational procedures of the dam (e.g., depth of release outlets, stratification pattern). Reservoirs with hypolimnetic discharges are characterized by reduced temperature variation, both diurnal and seasonal, with temperatures depressed in summer and elevated in winter. This type of regime, observable in the post-impoundment period at some stations downstream of Dartmouth Dam, has been cited as a major cause of reduction of species diversity in receiving streams (Hilsenhoff, 1971; Lavis and Smith, 1971; Spence and Hynes, 1971; Lehmkuhl, 1972; Ward, 1974; Ward and Short, 1978).

Ward (1976) reviewed the effects of altered flow regimes below dams. He identified four distinct flow patterns, depending on the operational procedures – the reduction or reversal of seasonal variation resulting from storage during peak run-off periods, and release during periods of low flow, short term flow fluctuations (e.g., hydroelectric dams), long term reductions of flow (e.g., during filling) and periods of increased flow (e.g., irrigation releases). Each of these effects has occurred at Dartmouth at various times. The constant riparian release during filling led to both low flow rates and a constant seasonal pattern, testing of the outlet towers resulted in a period of rapid flow fluctuations, while the recent irrigation release led to high flow at a time when flows are normally low.

These flow regimes have a variety of effects on the downstream fauna. Low flows can lead to the failure of respiratory or feeding mechanisms in species adapted to high currents (Edington, 1965). High flows can physically remove animals from the substratum (Kroger, 1973), destroy food sources or reduce habitat diversity (Radford and Hartland-Rowe, 1971). Short-term flow fluctuations lead to the sudden exposure of large areas of stream bed, lead to the sudden exposure of large areas of stream bed, with the subsequent dessication of large numbers of invertebrates (Fisher and LaVoy, 1972; Kroger, 1973) or induce catastrophic drift (Minshall and Winger, 1968). The alteration of seasonal flow patterns may disrupt current-cued life cycles or behaviour, or lead to a host of indirect effects, from oxygen depletion to channel modification (Ward, 1976).

The chemical composition of water retained in a reservoir is generally different to the water from the feeding stream (Hannan, 1979). The effect that this altered water quality has on the downstream section depends on operating conditions such as the outlet level and stratification pattern. Water drawn from low level outlets within the hypolomnion is typically low in dissolved oxygen, high in nutrients and occasionally high in certain potentially toxic ions and compounds (Krenkel et al., 1979). Reservoirs also act as clarifying agents, trapping run- off sediments from upstream leading to outflows that are low in suspended solids (Lehmkuhl, 1972). The high nutrient levels result in vast blooms of various types of algae, reducing habitats for some species, but providing food and habitat for others (Lowe, 1979). Toxic substances, such as hydrogen sulphide, can cause death of individuals in some species (Oseid and Smith, 1974).

Increasing the sediment load of the river, particularly during the construction phase of dams and roads (Rosenberg and Snow, 1975), with the consequent covering of the substratum with sediment, may have a serious effect on the fauna. Farnworth et al. (1979) reviewed the effect of sedimentation from various sources on macrobenthic communities with the conclusion that both density and composition are severly altered. However, they note that the effect of sediment penetration into the hyporheic zone is unknown. The hyporheos can be a vital component in the life histories of many species (Hynes, 1970), can be involved in daily vertical migration (Campbell, 1980), or be an important refuge in times of environmental stress (Coleman and Hynes, 1970; Hynes, 1974). The necessity of maintaining silt- free hyporheic habitats has been emphasised as a practice to reduce the deletrious effects of sedimentation in rivers (Eustis and Hillen, 1954; Armitage, 1978; Williams and Winget, 1979).

Construction (1972–1977)

Although construction on the actual embankment site did not commence until January 1973, activity in the area began as early as 1968 when exploratory trenching was carried out. In 1972, major works began with the construction of the acess road to the damsite. Hence, the initial survey of the macroinvertebrate fauna in 1974, intended to provide baseline date for comparison with later results, began after a considerable amount of land disturbance had already occurred.

Despite this, the 1974 data were indicative of a moderately diverse foothills community, transitional between that of a cool mountain stream and a warm, slow meandering river. Occasional taxa typical of cooler reaches were present (including some members of the Leptophlebiidae, Glossosomatidae and Conoesucidae), but were generally not as common as animals typical of slow moving waters (e.g., Caenidae) (Smith et al., 1978). The majority of the fauna however, required clean, fast water but was tolerant of warm summer conditions. This 'summer-warm' or 'foothills' group included most of the

Gripopterygidae,Baetidae, Siphlonuridae, Hydropsychidae, Leptoceridae, Tipulidae and Elmidae.

This is similar to the faunal composition found in section of the Mitchell River (Ahern and Blyth, 1978). The two rivers are very similar physically and, in the regions under study, had similar temperature regimes. Many species were shared between the two rivers.

The dendrogram representing site similarities for the 1979 collection (Fig.8a) suggests that there had already been some influence of construction activity on the fauna. Although all sites grouped closely together, the closer similarity between sites 1 and 5 (the two furthest apart in space) is of interest. Site 5 is in the typical lowland habitat and had already been somewhat influenced by agricultural activity, with a light silt layer and apparent nutrient enrichment, indicated by abundant growth of the filamentous alga, *Stigoeclonium* sp. That site 1 grouped more closely with this site, rather than the closer and visually more similar site 2, suggests that the first stages of bed sedimentation, and eutrophication by nutrients adsorbed to sediment particles, had already begun.

Although Graham et al. (1978) claimed that in the worst year only 33% of the total sediment load (measured by sampling suspended sediments) below the dam was due to construction activity, and this was negligible compared to natural year to year variation, sedimentation of the bed was the most significant physical change during the construction period.

The layered nature of the silt algal matrix formed downstream of the dam site indicates a circular interaction in which the increased sediment input stimulates the growth of some algae which trap more sediment, encouraging further algal growth, and so on. Interactions between sediment, adsorbed nutrient and algal growth are discussed at more length in EPA (1980) and West et al. (1984). The presence of motile species such as *Lyngbya* and *Oscillatoria* suggests a parallel with the formation of cyanobacterial mats with the same genera in other situations (Bauld, 1981).

Sediment deposits and associated algal blooms are frequent occurrences downstream of dams (e.g., Briggs, 1940; Eustis and Hillen, 1954; Hilsenhoff, 1979; Armitage, 1976), and Round (1965) notes that epilithic algae has the ability to trap suspended sediments. The layered nature of the sediment/algal complex has not been previously reported below reservoirs although patches have been observed during the construction of the Thomson Dam in Victoria (P. Brooks, NMV, pers. comm.).

The effect of this sedimentation on the faunal assemblage was dramatic. The dendrogram showing site similarities for the 1976 collection (Fig. 8b) shows that most sites on the Mitta Mitta River had become quite distinct from the control site on Snowy Creek. Construction activity had influenced site 1 to such an extent that it showed little faunal relationship to all other sites.

The major changes involved a large increase in the abundance of Oligochaeta and some species of Chironomidae with a concomitant reduction in species from a variety of taxa, particularly from the typical cool water and summer-warm components of the fauna. Many chironomid larvae can feed on algae as well as organic detritus (Williams, 1980). In particular, the genus *Cricotopus* one of the taxa which became abundant downstream of the dam site, has been shown to thrive in a sediment-affected stream in Wales (Learner et al., 1971) and a stream below a reservoir in Virginia (Simmons and Voshell, 1978). That other species of Chironomidae were observed to be adversely effected by the changing of the river, particularly at the more heavily sedimented sites, indicates the wide range of environmental tolerances of species within this family.

Oligochaeta, particularly the family Naididae, became extremely abundant over the construction period, presumably as a reaction to the sediment microflora layer in which they live and feed. Many oligochaete species have been reported to be enhanced by symptoms of mild organicpollution similar to that occurring in the river (Brinkhurst and Jamieson, 1971).

Almost all the species of Elmidae, the most diverse group of 'foothills' species, that were collected in 1974 were observed to decline in abundance during construction. Elmids are regarded as indicator species for clean, well-aerated waters (Williams, 1980) and, although often herbivorous, were adversely affected by the reduction of clean, stone surfaces, upon which they graze. One species (*Austrolimnius* sp L10E) was not as seriously affected as the rest, and this species appears to be particularly widespread and tolerant to a variety of environmental conditions (Blyth, unpublished data).

Other taxa disadvantaged by the changing physical conditions in the river, although not to the extent of the Elmidae, were the *Agapetus* and *Atalophlebioides*, both cool water forms and common on clean stone surfaces in fast flowing reaches of streams (Williams, 1980).

The sedimentation resulted in a much more uniform habitat, covering cobbles, pebbles and gravel beds, as well as filling spaces between grains of gravel and sand. EPA (1980) and West et al. (1984) showed that the sediment in the Mitta Mitta River during construction was predominantly fine sand (0.125–0.25 mm) and silt (0.00 – 0.063 mm), and suggested that large quantities of sediment penetrated deep into the bed. The effect on migratory species, using the hyporheos during part of their life cycles, is unknown, but may be more significant than the effect of surface sedimentation. The superficial nature of scouring brought about by a major irrigation release from Dartmouth Dam in 1980/81 was noted by Doeg (1984). West et al. (1984) discussed the longevity of fine sediment deep within the bed and concluded that its removal will occur extremely slowly, if at all.

Despite the fact that sediment deposits frequently occur below dams and the deleterious impacts are well established (Farnworth et al., 1979), there has been little work associating changes in the faunal community with the increase in construction sediment. Most overseas studies commenced during the filling and operation phase of the dam, so more attention has been given to changes in temperature, flow and water quality parameters. The resultant fauna reported from these studies is similar in composition to that present in the Mitta Mitta River at the end of the construction period, suggesting that much of the oft-reported deleterious impacts of impoundments occurs or commences as a result of activities during the early phases of construction, rather than only after impoundment.

Dam closure

The commencement of impoundment in November 1977 and the period of river stoppage for two weeks brought several dramatic changes to the nature of the river. The most noticeable was the exposure of the approximately 60% of the riffle zones in the upstream section of the study area. Kroger (1973) reported heavy mortality of invertebrates by stranding (about 34000 m^{-2}) in the Snake River, Wyoming, as a result of a rapid reduction of discharge from Jackson Lake Dam. Although no evaluation of the number of animals exposed in the Mitta Mitta River was made, it seems likely that the majority of animals in these areas did not survive.

Although river invertebrates are rarely seen in daylight (Hynes, 1970), high rates of drift, including all major taxa, were observed during the first day of closure. Minshall and Winger (1968) have also recorded abnormally large daytime drift, amongst all common taxa, in response to rapid reduction in discharge. Pearson and Franklin (1968), Radford and Hartland-Rowe (1971) and Gore (1977) observed large increases in nocturnal drift in relation to flow alterations. In this case, daytime drift rates were at least ten times greater after dam closure than before, but this was sill much less than the corresponding night time rates (Blyth, unpublished data), retaining the natural diurnal pattern (Waters, 1972).

The increase in emergence of some species may be correlated with the rapid warming of the water during the no-release period (Fig. 4). It is well established that the speed of development of many invertebrate taxa is increased by higher temperature (e.g., Jonasson, 1979; Sweeney, 1978; Sweeney and Vannote, 1978). The rapid warming of the river water after closure may have been instrumental in hastening emergence in a number of species at Dartmouth. It is not known what proportion of the adults succeeded in mating and laying eggs. No other records of mass emergence of adult insects following dam closure has been reported in previous studies of regulated streams.

Samples taken in November 1977 before and after dam closure, appear to conflict with the observation that large numbers of invertebrates perished after dam closure. There was no significant decline in the number of taxa collected, and a very large increase in the number of individuals. However, the bulk of the individuals were newly hatched members of a few species of Hydropsychidae, in which hatching was presumably hastened by the increasing temperature. By February 1978, the great bulk of these small individuals had disappeared. Further, great concentrations of current loving species in the reduced riffle area survived for a short time only after dam closure.

Filling

The conditions in the river in the foothills section of the study area over the first year of impoundment were characterised by low, constant discharge, depressed summer and elevated winter temperatures, and poor water quality. These effects were somewhat ameliorated by the inflow of various tributaries and, apart from comparatively reduced discharge, were almost undetectable at Tallandoon.

In the dendrogram showing site similarities for October 1978 (Fig. 8c), site 1 shows little relationship to all other sites, sites 2, 3 and 5 appear as a group, and sites 4A and 7 as closely linked with the control site on Snowy Creek. Site 4A was located just below the confluence of Snowy Creek and, after dam closure, flow, temperature and water quality were mostly determined by conditions in the tributary, rather than the main river. The algal/sediment complex at site 4A, patchy during construction, totally disappeared after closure (although subsurface silt remained) and some recolonization from Snowy Creek could be expected.

At the foothill sites, the period of riparian release was marked by the extirpation of may of the 'foothills' components of the fauna, already disadvantaged by the effects of construction. Site 1 was the most deleteriously affected, with the almost complete elimination of the families Gripopterygidae and Elmidae. Many other species continued to decline at this site (e.g., *Coloburiscoides* sp., *Tasmanocoenis* sp., many of the Chironomidae) with the result that by the time of the construction of the pondage weir which eventually inundated this site, only five species were regarded as common and about 90% of the fauna was dominated by Oligochaeta and *Cricotopus* spp.

Sites 2 and 3 were not as severely effected, although the Elmidae and Gripopterygidae continued to decline. Several species increased in abundance over this period, the most notable being the Hydropsychidae, often reported as being abundant downstream of impoundments (Ward, 1976). However, there was no evidence of any recovery of taxa present in 1974 that were eliminated during the construction period.

Site 5 appeared to be little influenced by the changed regime after impoundment. The fauna collected in 1978 closely corresponded to that found in 1976, indicating the influence of the inflows of unregulated tributaries and the distance downstream of the dam. Many authors have stated that, with increasing distance from the dam, atmospheric conditions and the inflow of large quantities of tributary waters combine to produce a recovery, returning the river to pre-impoundment conditions and a resulting rise in faunal richness (Pearson et al., 1968; Ward, 1974; Gore, 1977, 1980; Fraley, 1979; Williams and Winget, 1979). However, Radford and Hartland-Rowe (1971) show that this recovery is not total, with species richness being depressed in comparison with similar unregulated rivers.

At site 5, the latter view appears to be most likely. Although there has been little influence of the post-impoundment conditions at this site, there is no evidence of a recovery towards the pre-construction faunal assemblage. Thus, the effect of construction activity may have had a greater range of influence than the more traditionally accepted causes of reduction in species diversity (flow, temperature and water quality).

Conclusions and summary

This study deals with the impact of the construction and initial filling period of Dartmouth dam on the benthic invertebrate communities downstream of the dam site. Despite problems associated with changing sampling techniques, the change in various community properties is fairly clear and consistent. Since 1974, stations downstream of the dam have undergone a reduction in diversity, changes in abundance, and a change in faunal composition, with the loss of species adapted to head-

water and foothill conditions and the extension of more tolerant species.

The most significant effect on the fauna seems to have been the increase in sediment bed load, forming a thick silt/algal matrix over the entire river substratum at sites close to the dam. This sedimentation followed the classic pattern of pollution from a point source, reducing in intensity with increasing distance from the dam site. The effect on the fauna extended over all study sites, leading to a great increase in the number of individuals of Oligochaeta and a few species of Chironomidae. Species requiring the clean substrata were greatly reduced in number. This occurred prior to alterations to discharge.

Dam closure, as a single acute impact, destroyed many of the macroinvertebrate organisms originally existing on the river bed between the dam wall and Mitta Mitta township. Primary factors contributing to this mass mortality were the stranding of animals in areas of the bed which became exposed as a result of the decreasing flow, a large increase in the drift rate and the premature emergence and death of adults due to the rapid heating of the river.

The period of riparian release, including several periods of no release, placed several stresses upon the aquatic biota. Changes to the historical flow and temperature regime and lowered water quality (resulting from the breakdown of inundated organic material) all led to further reductions in diversity, particularly at sites close to the dam. Further downstream after the input of several tributaries, the effect of the change in the release pattern was minimal.

Impacts on the fauna have been of two broad types: acute effects which eliminated many animals and species in a single short term event, such as dam closure; and chronic effects, such as bed sedimentation and changes to the flow and temperature regimes, which gradually caused the elimination of certain taxa over the long term.

Much of the previous work on regulated streams has found a similar decrease in faunal richness to that reported here, and various changes to the temperature and flow regimes have been cited as the major factors causing this reduction (e.g., Hilsenhoff, 1971; Ward, 1974, 1976; Ward and Short, 1978; Ward and Stanford, 1979). However, this present study emphasises the effects of the construction period and the increased input of sediment into the river. As most previous studies have begun after the completion of the dam, little attention has been paid to the pre-impoundment changes in faunal diversity and composition.

Alteration to stream-bed structure brought about by construction sediment may be extremely long term. Further, although reservoirs act as clarifying agents, removing sediment from incoming waters (Lehmkuhl, 1972), the low release during the filling period allows further deposition of naturally eroded suspended material which would normally be dispersed further downstream. This was observed after the irrigation release (Doeg, 1984). Thus, much more research is needed on the movement, impact, and removal of erosion sediment in stream environments.

The future management procedures of dams under construction must take into account efficient methods of sediment control during the building phase as well as careful planning of release strategies, if the preservation of environmental quality, as measured by macroinvertebrate species diversity, is to be obtained.

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Appendix 1. Description of study sites.

Station	Locality	Distance below dam site (River km)	Width (m)	Depth (cm)	Current	Substratum	Remarks
1.	Between Dartmouth township and the dam wall	2	20	10-40	v. fast	Solid rock outcrops with cobbles and pebbles	Inundated with pondage weir in 1978
2.	Below site for pondage weir	10	15	10-60	fast	boulders and cobbles	Flows through gorge
3.	Between Mitta Mitta township and Callaghans Creek confluence	17	10	10-50	Moderate - fast	cobbles and pebbles	Willows present, river leaving gorge area
4A	Mitta Mitta camping area below Snowy Creek confluence	25	20	25-50	Moderate - fast	cobbles and pebbles, few boulders	In cleared land but no grazing
5.	Tallandoon picnic area	50	25	20-40	Moderate	cobbles and pebbles	Willows present, much algae. In cleared, heavily grazed land.
7.	Snowy Creek upstream of Mitta Mitta township		6	40-60	fast - v. fast	boulders and cobbles	Cooler stream

*current was much reduced at sites 1-4A after dam closure.

Appendix 2. Relative abundance of each taxon collected at each site for three sampling trips; (Feb. 1974, Oct. 1976 and Nov. 1977). Abundances are given as 1, rare; 2, common; 3, abundant; 4, very abundant.

	Site 1			Site 2			Site 3			Site 4A			Site 5			Site 7		
	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978
Platyhelminthes																		
Dugesiidae	1		1			2	1					1	2		1			
Annelida																		
Oligochaeta	2	3	3	2	3	3	1	3	3		4	3	1	4	4	2	2	2
Mollusca																		
Gastropoda	2		1	3	2		2	1	1		2		1	1	1		1	
Arachnida																		
Hydracarina	2	1	1	3	2	1	2	1			1	2	3	2	3	2		1
Insecta																		
Ephemeroptera																		
Leptophlebiidae																		
Atalophlebioides spp.	1	1	1		1		1	1	2		2	2	1	1	3		2	2
Baetidae																		
Baetis spp.	2		2		1	1	3		2		2	2	2	1	1	3	2	2
Siphlonuridae																		
Coloburiscoides sp.	2	1		1	2		2	2	1		2	1	2	1		2	1	1
Caenidae																		
Tasmanocoenis sp.	3	1		4	1	2	3	1			2	1	4	2	3	1		2
Odonata																		
Gomphidae		1	1	1	1	1		1	1		2	2		1	2			1
Aeshnidae	1		1			1	1		1		1	1	1		1		1	1
Plecoptera																		
Gripopterygidae																		
Illiesoperla australis																		
Tillyard	1						1	1	2		2	1	1	1	1	1		1
Trinotoperla nivata Kimmins	2	1			2		1	2			2	2			1		2	1
T. yeoi Perkins												1						1
Riekoperla rugosa (Kimmins)																		1
R. williamsi McLellan					1			1	2		1	1		1	1			1
Leptoperla bifida McLellan														1				
L. primitiva McLellan												1						
Dinotoperla arenaria Hynes	1						1							1		2		
D. brevipennis Kimmins		1	1		1		1				2	1		1			1	
D. fontana Kimmins	1		1		2						1			1	1			1
D. serricauda Kimmins	2	2		1	2	2	2	2	3		2	1	1	2	3	1		1
Megaloptera																		
Corydalidae	2		1	2	1	1	2	1	1		1	1	1		1	2		1
Coleoptera																		
Elmidae																		
Austrolimnius waterhousei																		
Hinton (sp.L34E)	1	1		2	1	2	2	1	2		1		1	1	2	2		
A. sp. L10E	3	2		3	2	3	3	2	3		3	3	3	3	2	3	1	2
A. sp. L13E				1			1	1			1			1		2		
A. sp. L14E		1																
A. sp. L25E				1	1						1			1				
A. sp. L35E														1				
A. sp. L40E						1						2						
A. sp. L67E						1												
Kingolus sp. L1E	3	2	1	3	2	1	3	2	1		2	1		2	1	2	1	2
K. sp. L5E		1										2						
K. sp. L7E		1		2			2				1		1		1	1		
K. sp. L29E	1			2			2						1			1		
Simsonia hopsoni																		
Carter & Zeck (sp. L4E)	1			1	1		2				1	1				1		
S. sp. L2E	2	1		1	1		2				1		1			1	2	
S. sp. L3E	1	1	1	1	1	1	1		1		1		1	1		3	2	
S. sp. L13E												1						1
Notriolus maculatus																		
Carter (sp. L9E)											1	1						
N. allynensis Carter																		
(sp. L18E	2									1								
N. quadraplagiatus																		
Carter (sp. L43E)												1						
N. sp. L6E							1									1		
N. sp. L57E							1								1			
Elmidae sp. L15E													1					
Hydrophilidae																		
Berosus sp.	1		1	2			2											
Psephenidae																		
Sclerocyphon sp	2	1	1	2	1	1	2	1	1	2		1	1	1	1	2		2
Diptera																		
Tipulidae sp. 2	3	1		3	2		3	1	2		1	2	2	2	1	1		
Tipulidae spp.	1		1		1	1			1	1	1	1		2	3			
Empididae	3	2	2	3	2	1	2	1			1	1	2	1	2	2	1	1
Simuliidae		2	1	1	1	3			3		1	3	2	1	3	3	2	3
Ceratopogonidae	2	1	2	1		2	2	1	2		1	1		1	2	1		
Chironomidae	2	1	2	1	2	2	2	1	2		1	1		1	2	1		
Orthocladiinae																		
Eukiefferiella sp. 1 (2E)	3	3		2	2		3	1	1		1		2	1	2	2	1	2
E. sp. 2 (70E)		1	1		2	2		3	2		3			3	3		2	2

Appendix 2. (continued).

	Site 1			Site 2			Site 3			Site 4A			Site 5			Site 7		
	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978	Feb 1974	Oct 1976	Nov 1978
Cordites sp. (9E)	1			1		1		1	2		1		1	1				1
Thienemanniella sp. (10E)		1				1			3		1			2	3		1	2
Cricotopus sp. 1 (12E)	2	3	3	1	4	3	1	3	3		3		1	3	4	1	2	2
C. sp. 2 (31E)					1													
Cardiocladius sp. (39E)	2	1		2	2	2	2	2	2		2		2	3	2	1		
Erycnemus sp. (69E)							1											
Corynoneura sp. (63E)						2					1			1	2		1	2
Chironominae																		
Dicrotendipes sp. (30E)					1													
Stenochironomus sp. (3E)					1		1											
Rheotanytarsus sp. (4E)				1		2	1		3		1				2		1	
Riethia sp. (5E)	1	1		1	1						1		1	2		2	2	2
Crytochironomus sp. (13E)	1			1		1							1					
Seatheria sp. (15E)														3				
Polypedilum sp. (16E)	2					1	1		2		1		1			1		
Calopsectra sp. 1 (22E)											1							
C. sp. 2 (36E)	1												2					
Kiefferulus sp. (87E)				1			1						1					
Psectrocladius sp. (93E)			2			2												
Parachironomus sp. (104E)						2												
Tanypodinae																		
Ablabesmyia sp. (7E)		1																2
Macropelopia sp. (27E)					1			2			1			1			1	
Pentaneura sp. (32E)	1	1		1		2							1		2	1		
Procladius sp. (66E)	2	1		1	2		1	1			2		1	2	2	1		
Diamesinae																		
Paraheptagyia sp. (23E)		1	1		2			2			2			2	2		1	2
Podonomiinae																		
Podonomopsis sp. (71E)														1	2		1	1
Aphroteniinae sp. 18E		1			2	2		2			2			1	2			
Unidentified sp. 35E											1							
sp. 45E								1										
sp. 55E								1			2							
sp. 72E														1			1	
sp. 86E																		1
Tricoptera																		
Hydropsychidae																		
Austropsyche sp. (sp. 1)	1			1			1									3	3	
Smicrophylax sp. (sp. 2)																		
S. sp. (sp. 10)																		1
Asmacridea edwardsi (McLachlan)																		
A. sp. 3		1		1	2	1			2		2	1	1	2	1	1	1	1
A. sp. 8											1							1
Cheumatopsyche sp. 1 (sp. 4)						1			1			1			2			
C. sp. 2 (sp. 5)	1			2	1	1	3	1	2		1	1	3	1		2	1	
Hydroptilidae	3	1	1	3	1	1	4		1			1	2			2	1	
Glossosomatidae																		
Agapetus sp.	2	1		2		1	3				1	2	1			3	2	2
Leptoceridae	2	2	1	1	1		1	1	2		2	2	2	1	1	3	2	2
Conoesucidae	2	2		2	2	1	1	1	1		2	2	1	1	1	2	3	2

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Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria, to the construction and operation of Dartmouth Dam. 2. Irrigation release.

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Abstract. Doeg, T.J. (1984) Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria, to the construction and operation of Dartmouth Dam. 2. Irrigation Release. *Occ. Pap. Mus. Vict.* 1:101–8.

The effect of a large irrigation release (8000 Ml day^{-1} for 3 months) on the macroinvertebrate fauna in the Mitta Mitta River below Dartmouth Dam was studied over a period of 13 months. The hypolimnetic release produced the predicted effect of a major spate, reducing the number of taxa at sites close to the dam but having no discernible impact further downstream. In the following summer, there was a general reduction in faunal richness compared with prerelease levels, at sites upstream of the major tributary, Snowy Creek, while a site downstream of Snowy Creek returned to prerelease numbers of taxa. The reduction was attributed to the disruption of life cycle events of some species by the high flow and depressed temperature of the release, leading to a failure to produce the next generation of individuals.

A brief review of the critical events during the construction and operation of Dartmouth Dam is also included, indicating that the major cause of the changes in diversity and composition may be the increase in sediment bed load observed during construction. Postimpoundment changes to temperature, flow and water quality seem mostly to continue the elimination of species already disadvantaged.

Introduction

Dartmouth Dam, impounding 4 × 10^6 Ml on the Mitta Mitta River in north- eastern Victoria, was constructed between 1972 and 1977. Its major purpose is to provide large scale irrigation support to Hume Reservoir on the Murray River during long, dry periods. Thus, management of Dartmouth requires long term storage and occasional large releases, probably during the summer months. Such a release, mainly of hypolimnetic water, occurred between December 1980 and March 1981 with a mean discharge of approximately 8000 Ml day^{-1} for three months. The effect of this first major operational release on the macroinvertebrate fauna forms the basis of this report.

At the time of the irrigation release, the macroinvertebrate communities of the Mitta Mitta River below the Dartmouth Dam had already been altered by the effects of construction, dam closure and filling (Blyth et al., 1984). A typical foothill fauna of high diversity with common species in the families Lepthophlebiidae, Elmidae, Gripopterygidae and Glossosmotidae had been reduced to one of low diversity, dominated by more tolerant species from the Chironomidae and Oligochaeta. Sites on the river flats appeared to be less effected during impoundment than foothill habitats.

Procedures and methods

Study area and sampling sites

The study area, shown in Fig. 1, covers the Mitta Mitta River below the wall of the Dartmouth Dam to Tallandoon, about 50 km downstream and was described by Blyth et al. (1984).

Three sampling sites on the main river and one on Snowy Creek, the major tributary, were chosen, corresponding closely to sites sampled in previous surveys (Blyth et al., 1984).

Site 3A, 200 m upstream of the inflow of Callaghans Creek, is in the typical upland section of the study area. The river here consists of a small rapids section flowing through an outcrop of bedrock into a large deep pool and a slow deep run. Site 4B at Mitta Mitta Township, 100 m upstream of the confluence of Snowy Creek, was a large, comparatively slower run over a bed of large cobbles. Site 5, located near Tallandoon, was in the cleared lowland zone where the river is wide and flows over a bed of smaller cobbles, pebbles and gravel. At each of these sites, the river was arbitrarily divided into fast and slow areas, defined as those with currents of over 70 cm sec^{-1} and under 40 cm sec^{-1} respectively.

Site 4C on Snowy Creek (only sampled from August 1981) was located 200 m upstream of the confluence with

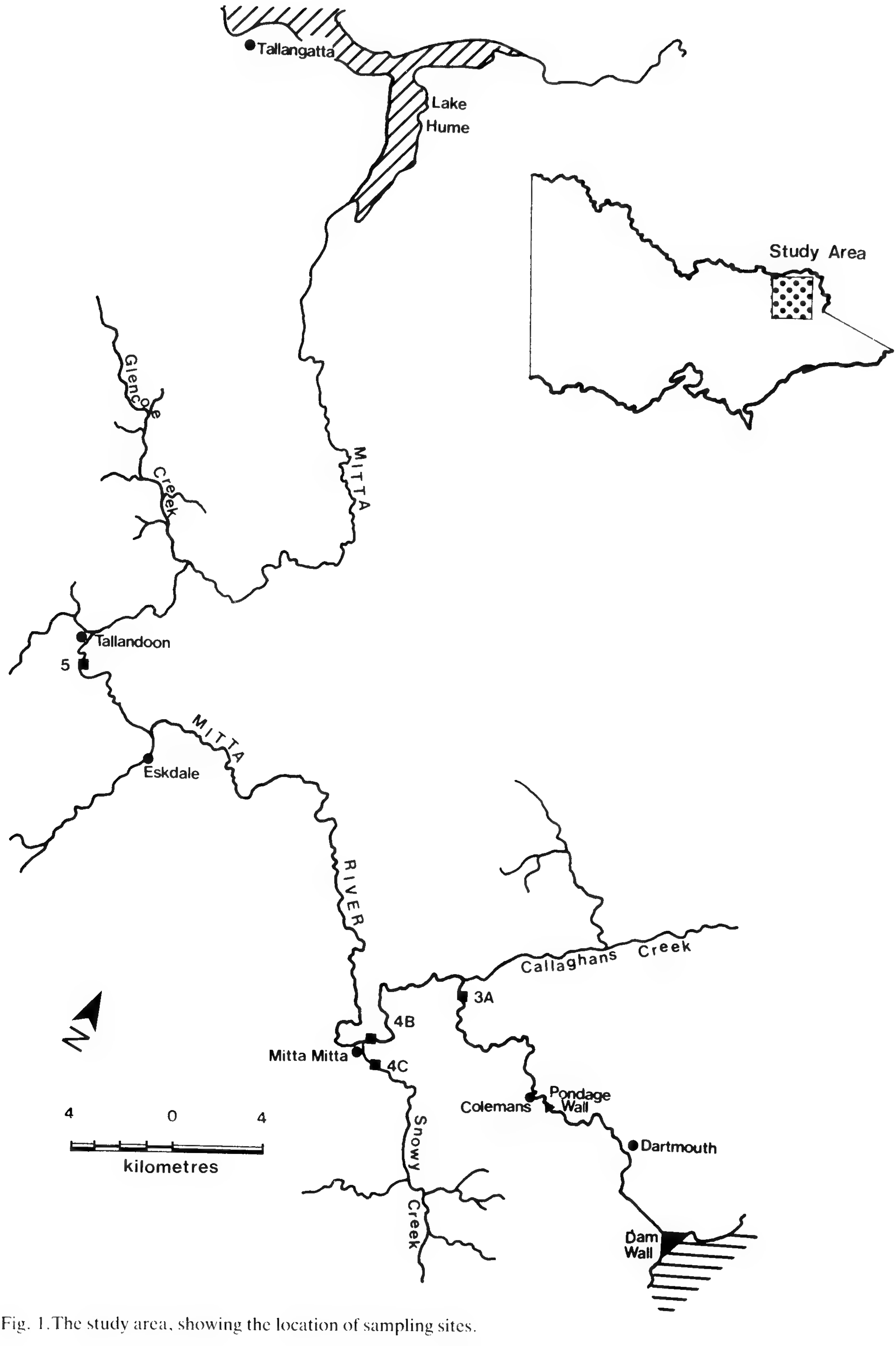

Fig. 1. The study area, showing the location of sampling sites.

the Mitta Mitta River. The flow here was consistently fast (no slow areas could be identified) and the substratum consisted of cobbles, pebbles and gravel.

Collecting trips
Six collecting trips were undertaken during the period from December 1980 to March 1982: 1–2 December 1980; 12–13 March 1981; 6–7 August 1981; 7–8 October 1981; 2–3 December 1981; 4–5 March 1982. This covers one set of pre-release samples and five sets in the 12 months following the end of the release.

Collecting methods
A set of five kick samples was taken at each of the two current speed categories at each of the sites. A standard time of 30 seconds agitation for each sample was used. The substratum was disturbed to a depth of between 5 and 10 cm and covered an area of approximately 0.5 m^2. Dislodged material was collected in a 160 μm mesh dip net held just downstream of the operator's feet.

Samples were transferred to plastic jars and preserved in a 10% formalin solution; Rose Bengal was added to contrast animals against other collected material.

Sorting and identification of specimens
In the laboratory organic and inorganic material were separated by flotation in a calcium chloride ($CaCl_2$) solution. The inorganic fraction, after careful examination for Mollusca and cased invertebrates, was discarded. The organic fraction was subsampled to 1/10th of its original volume. All animals in the subsamples were separated from organic detritus by hand under a stereomicroscope and preserved in 70% ethanol.

Where possible, specimens have been identified to species using the collection of the National Museum of Victoria (NMV). Where groups could not be identified in this manner, presumptive species were allocated code numbers in line with the voucher specimen system being developed by the Biological Survey Department.

Physicochemical results
Discharge
Daily discharge (in Ml) for three sites on the Mitta Mitta River and Snowy Creek for the period November 1980 to April 1981 are shown in Fig. 2. Gauging stations at Tallandoon and Snowy Creek are close to sites 5 and 4C respectively, and Colemans station is 10 km upstream of site 3A.

From Blyth et al. (1984) the mean monthly discharges (in Ml day^{-1}) at Colemans station for December, January and February in the period 1967–1977 (i.e., prior to dam closure) were 1573, 1179 and 993 respectively. After closure (1977–1980), the equivalent values were 166, 173 and 150 Ml day^{-1}. Hence, the irrigation release (monthly discharges of 3578,7371 and 8858 Ml day^{-1}, although only half of December was effected by the high flow) represents an increase of between 100 and 800% over historical mean discharges and between 2000 and 6000% over the mean flow during the filling period.

At Tallandoon, the mean historical discharges for the three months were 3208, 1714 and 1371 Mlday^{-1} and the postclosure values were 643, 418 and 290 Ml day^{-1}. The release (4133, 7489 and 8720 Ml day^{-1}) represents an increase of between 20 and 550% over preclosure values and between 550 and 3000% over the flow during filling.

Physical and chemical factors
Values for nine physicochemical parameters (measured as part of the SRWRC comprehensive survey of Victorian river systems) were obtained covering the period from December 1979 to January 1982. The results, presented in Fig. 3, were recorded at Colemans, Tallandoon and Snowy Creek gauging stations described above.

pH (Fig. 3a): Measurements of pH were reasonably constant and equal at all sites with little evidence of variation due to the differing flow regimes or the irrigation release.

Electrical conductivity (EC) (Fig. 3b) and Total Dissolved Solids (TDS) (Fig. 3c): Recorded values of EC and TDS display similar patterns. Results at Snowy Creek and Tallandoon show a relatively narrow range of values with evidence of seasonal variation, being highest in autumn and lowest in spring. Measurements at Colemans show generally higher values with no seasonality. Minimum values of both parameters at this site were recorded during the irrigation release, when all three sites had similar EC and TDS readings.

As both EC and TDS usually vary inversely with discharge (Hynes, 1970), it seems probable that the patterns displayed are the result of the differing flow regimes at each site.

Turbidity (Fig. 3d) and suspended solids (Fig. 3e): Values of turbidity and suspended solids normally vary together, directly with discharge (Hynes, 1970), and this is the case in Snowy Creek, with maximum values recorded in periods of high natural discharge. However, at Tallandoon, the irrigation release, in which the high flow was of clarified reservoir water and not a result of rainfall, led to a decrease in turbidity, but an increase in suspended solids. At Colemans, both factors displayed considerable, largely unrelated, variability.

The differences observed may be partly due to more rapid scouring, and scouring by lower flows, of colloidal material (which contributes largely to turbidity), than of the larger particles comprising suspended solids during the irrigation release.

Iron (Fig. 3f) and manganese (Fig. 3g): Iron and manganese concentrations recorded at Colemans during 1980 were particularly high. The lowest recorded values were found during the irrigation release and similar high levels were not detected for the remainder of the study period, although manganese concentrations fluctuated considerably over 1981.

Concentrations in Snowy Creek were typically lower and constant (except for an anomalous iron reading of 0.96 mgl^{-1} in October 1981). The recordings from Tallandoon show the diluting influence of the output from Snowy Creek. Seasonal patterns followed those at Colemans, but the values were mostly intermediate between those of Snowy Creek and the upper Mitta Mitta River.

Temperature (Fig. 3h): Recordings of temperature showed seasonal patterns at all sites with summer maxima and winter minima. However, during the irrigation release, temperatures at Tallandoon appeared to be depressed by about 46°C, compared to the previous summer, and by about 2°C at Colemans. Compared to pre-construction values Blyth el al. (1984) showed that the temperature depression during the release was 10°C at Colemans and 9°C at Tallandoon. There was no similar reduction at Snowy Creek.

Dissolved oxygen (Fig. 3i): Levels of dissolved oxygen

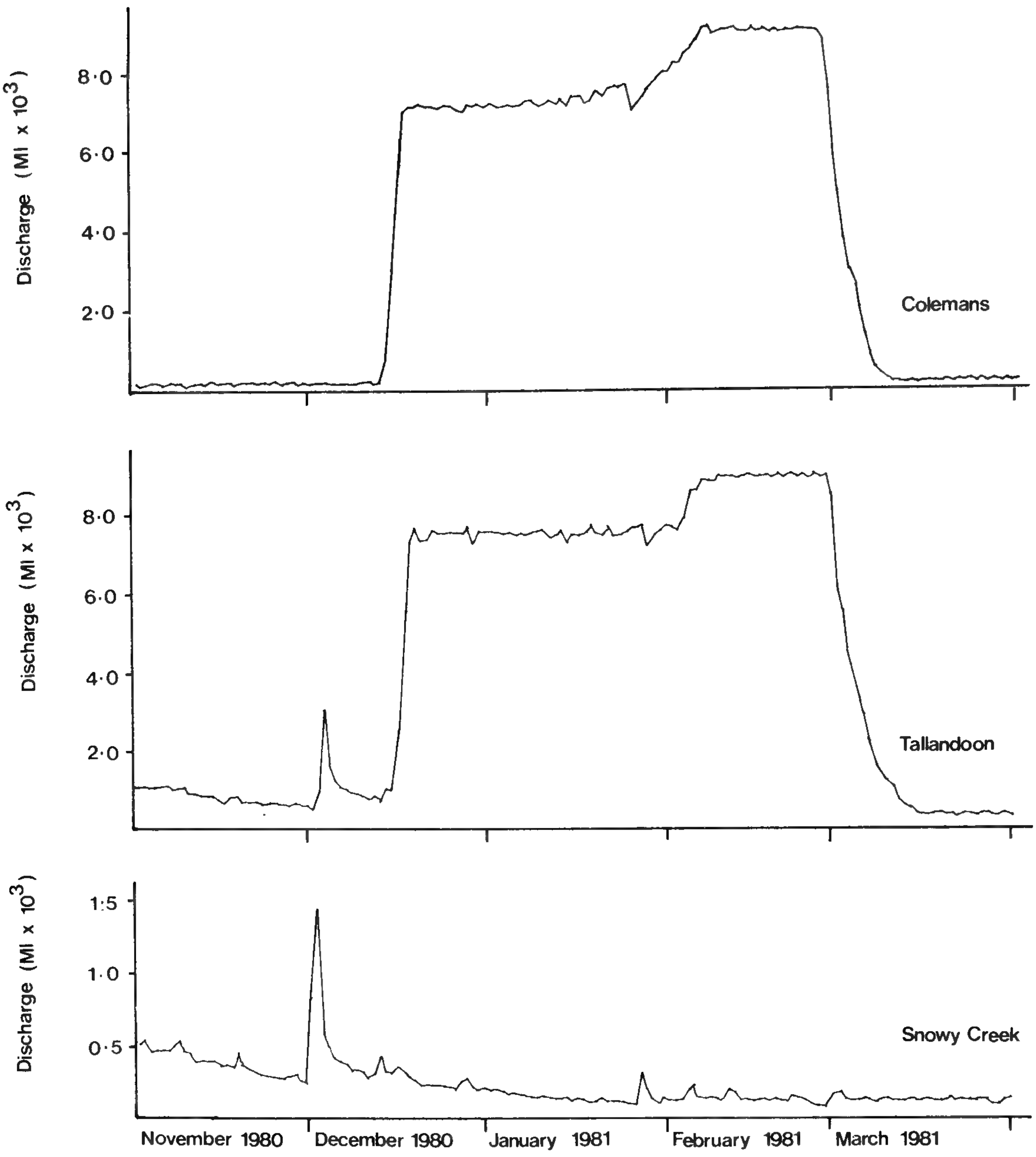

Fig. 2. Daily discharge (in Ml) over the period November 1980 to March 1981 at three gauging stations in the study area (SRWSC, unpublished data).

are rarely low in turbulent lotic systems (Hynes, 1970), although releases of hypolimnetic water can have low oxygen levels, particularly during summer stratification (Krenkel et al., 1979). Although the water released over the summer of 1980/81 had oxygen levels as low as 56% (SRWSC, unpublished data) the oxygen level at Colemans was never below 90% and was often supersaturated. This was the case at Snowy Creek also. At Tallandoon the lowest readings of 83% and 86% saturation were both in the summer. Over this period it seems unlikely that dissolved oxygen level imposed any significant stress on the macroinvertebrate fauna.

Field observations

Prior to the irrigation release in December 1980 abundant quantities of deposited sediment and attached algae were noted at sites 3A and 4B on the Mitta Mitta River, forming a thick layer over much of the slower reaches. In faster riffle zones this silt/algal matrix was reduced but large plumes of fine sediment were produced during sampling. At site 5 the surface layer of the sediment was much finer and abundant filamentous algae and subsurface silt were noted.

In the March 1981 trip, following the irrigation release, much of the surface sediment had been scoured from site

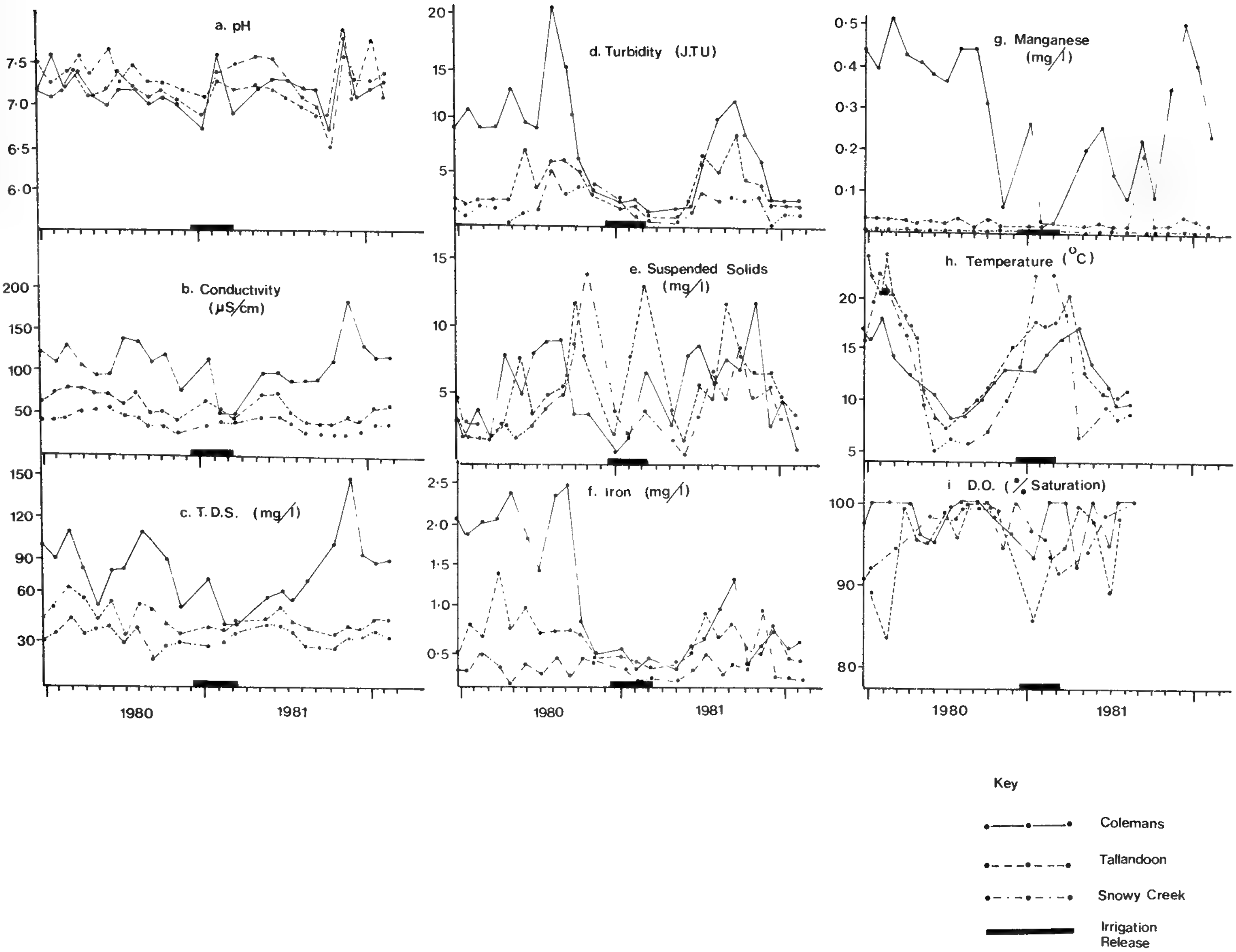

Fig. 3. Records of various parameters at three sampling stations in the study area (SRWSC, unpublished data).

3A although the sand/gravel fraction and some of the attached algae remained. Some effects of scouring were observed at Site 4B but not to the extent of that further upstream. At site 5 the effects of the release appeared to have been minimal with the layer of silt and filamentous algae remaining largely intact. Despite the heavy flow subsurface silt at all three sites, judging from the disturbance plume, was apparently unaffected.

During the 12 months following the release further surface siltation and algal growth was recorded until, in March 1982, the river substratum had returned to near pre-release conditions.

The fauna of fast water

Community structure of the Mitta Mitta River

Appendix 1 is a list of all identified taxa from all sites over the study period. Where possible, taxonomic names are given for the code numbers designated in the voucher system used in this laboratory.

The abundance of each collected taxon for each of the sampling trips at each site is given in Appendices 2 to 4.

The total number of taxa, and the mean number of taxa and individuals per sample at each of the three sites on the Mitta Mitta River (3A, 4B and 5) are presented in Fig. 4 (Site 4C, on Snowy Creek, will be discussed separately.

The initial impact of the irrigation release was only seen at site 3A, closest to the point of release. There was a dramatic reduction in the total number of taxa at this site over the release period (Fig. 4a) whereas numbers remained approximately constant at the two sites further downstream. The mean number of taxa per sample also reflected this change (Fig. 4b). One- way analysis of variance showed that the number of taxa per sample did not vary significantly between sites in December 1980 ($F = 2.71$, $df = 2, 12$), but there were significantly fewer species per sample at site 3A in March 1981 ($F = 16.86$, $p < 0.001$).

This is consistent with the recorded impact of major spates with a reduction in species diversity close to the source of the flood, but sites further downstream being unaffected (Hynes, 1970).

All three sites have similar, comparatively low, total numbers of taxa and mean numbers of animals per sample in previous surveys (Blyth, unpublished data) and are essentially a result of natural seasonal events.

In the following three trips, the total number of taxa collected at site 5 rose to pre-release levels, while both sites 3A and 4B remained depressed compared to the previous December levels (a reduction of about 25% at each site). The number of taxa per sample follows the same

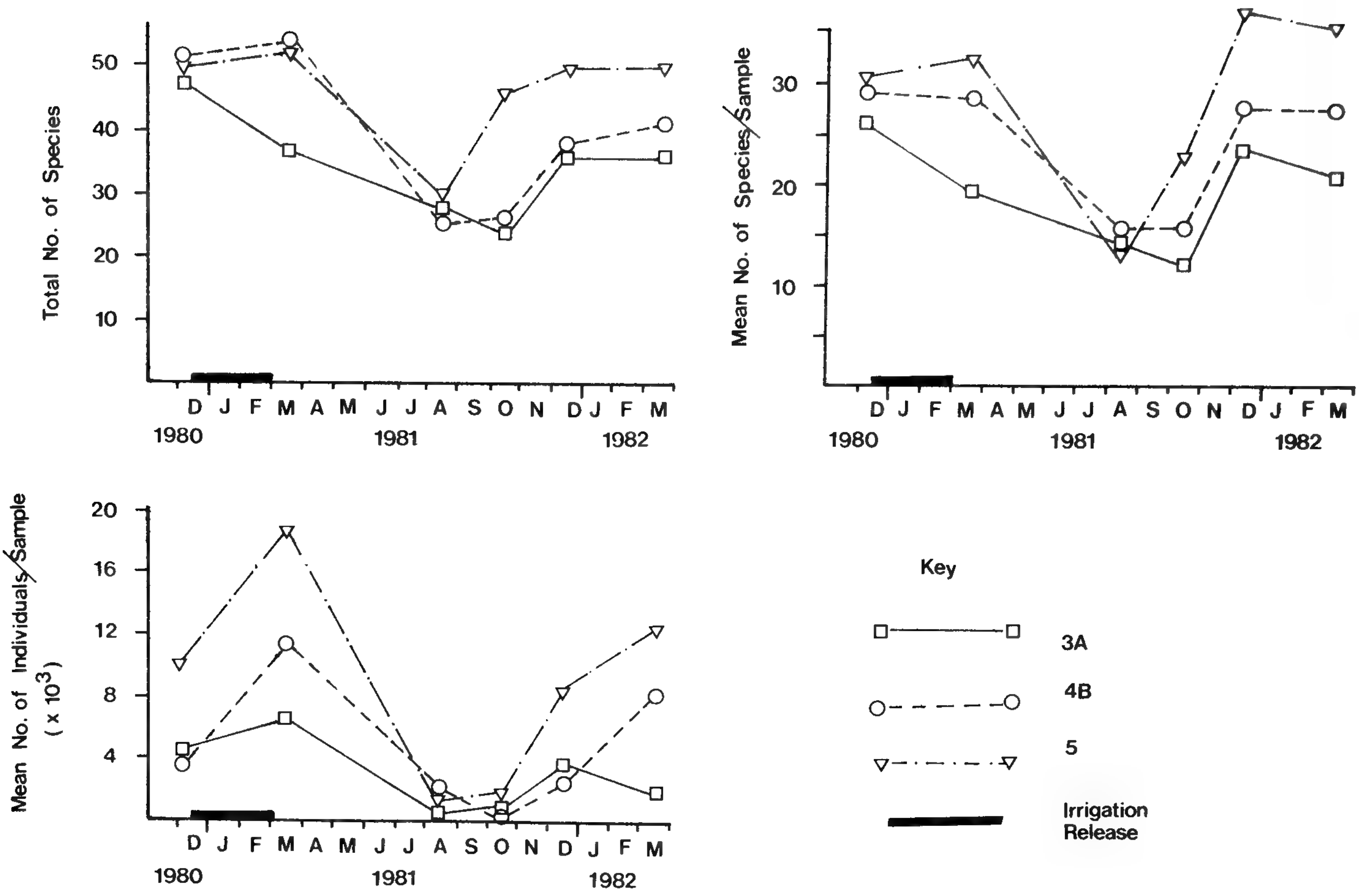

Fig. 4. Total number of species, density of species and density of individuals collected in fast water samples at each site on the Mitta Mitta River during the study.

pattern, being significantly lower at sites 3A and 4B than at site 5 on each occasion ($p < 0.001$ in October, $p < 0.01$ in December 1981 and $p < 0.001$ in March 1982).

The density of individuals is a far less sensitive parameter, varying considerably between samples, sites and dates. However, although the numbers of individuals per sample at sites 4B and 5 rise significantly over the pre-release period ($t = 4.43$, $p < 0.05$ and $t = 3.51$, $p < 0.05$ respectively), the rise at site 3A was not significant ($t = 1.50$).

Classification of the community of the Mitta Mitta River

Figure 5 presents a dendrogram showing relative similarity, based on the presence or absence of taxa (mainly species but including higher groups shown in Appendix 1), between each of the collections made over the study period. The Sorensen coefficient was used (Hellawell, 1978) with the flexible ($\beta = 0.25$) classification strategy of Lance and Williams (1967). A fusion level of 0.0 represents total statistical dissimilarity while a value of 1.0 shows total accordance between the collections being compared. Given natural sampling variation, levels around 0.7 can be regarded as displaying 'considerable' similarity, when comparing samples of benthic macroinvertebrates.

From Fig. 5 it can be seen that faunal assemblages in Snowy Creek are quite distinct from those found in the Mitta Mitta River. The associations between collections made in Snowy Creek will be outlined later.

Collections made in the Mitta Mitta River itself can be divided into two separate groups representing samples collected in December and March (hereafter referred to as 'summer' samples), and those taken in August and October ('winter' samples).

The summer samples can be further discriminated into collections made in 1980/81 and those made in 1981/82. there are also appreciable differences within each of these groups that are consistent with observations reported in Fig. 4. The samples from the summer of 1980/81 are clearly divided into those from December 1980 and March 1981. The high similarity between the sites for December 1980 indicates little faunal zonation in the river at that time. The immediate impact of the irrigation release, described above, can be detected as a reduction in similarity between site 3A and the other two sites.

In the summer of 1981/82, two different groupings are suggested, one being the collections at site 5 and those from sites 3A and 4B, reflecting the differences noted in Fig. 4(a, b) and suggesting the imposition of a degree of zonation on the fauna.

The winter samples are also divided on this basis with site 5 having a distinctly different faunal composition to sites 3A and 4B, although the August 1981 and October 1981 samples at site 5 have a relatively low similarity.

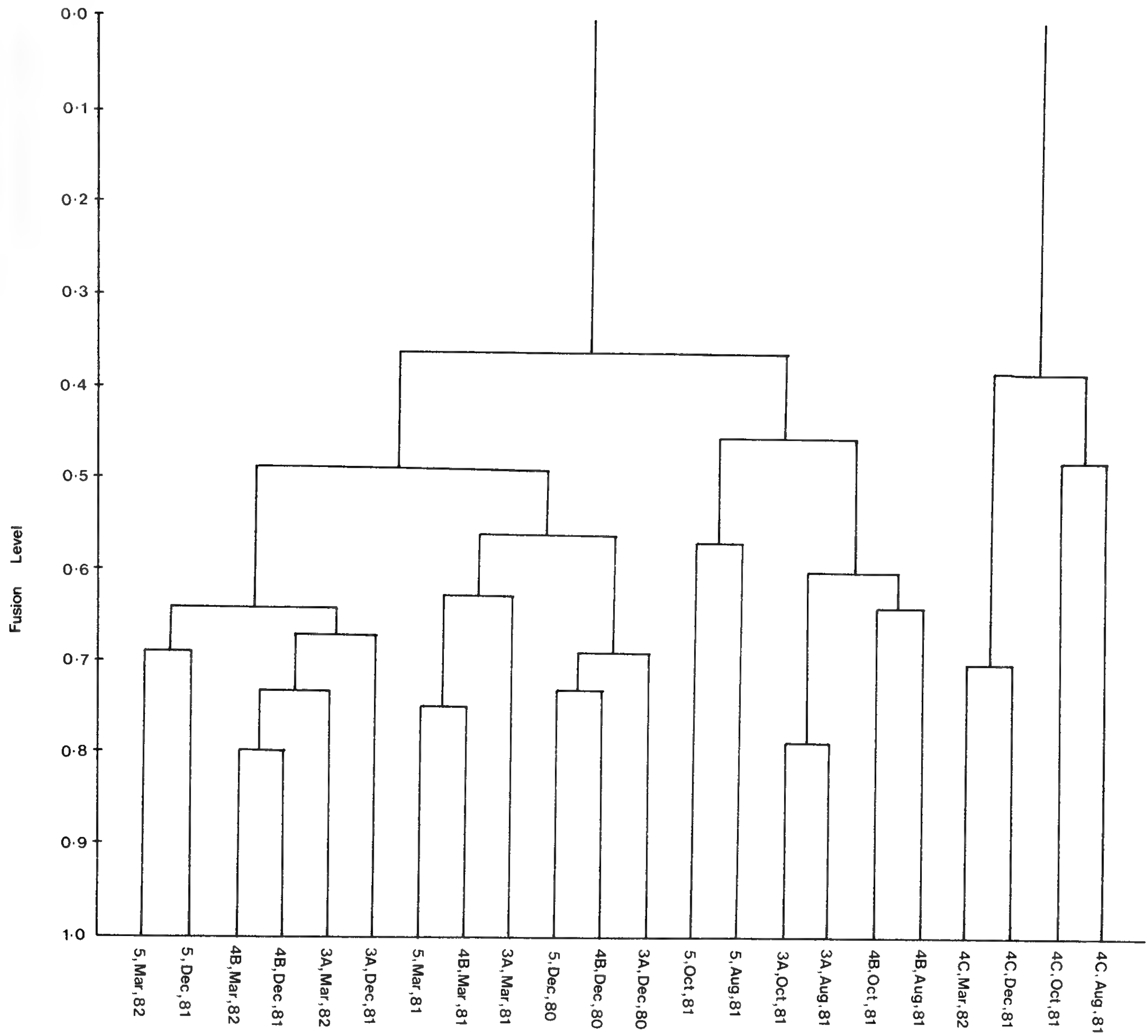

Fig. 5. Dendrogram showing community relationships between collections based on the Sorensen similarity coefficient and the flexible sorting strategy (Lance and Williams, 1967). Baseline indicates site and collecting date, e.g., 5, Dec, 80 refers to the collection made at Site 5 in December 1980. Only samples from fast water are included.

Community structure of Snowy Creek

The distinctly different faunal assemblages from Snowy creek and the Mitta Mitta River (Fig. 5) and the fact that no samples were taken in December 1980 and March 1981, lessen the value of Snowy Creek as a control. However, some observations from that tributary do have relevance and are included here.

A total of 140 taxa were identified from Snowy Creek, 46 of which (40%) were found only at that site. The abundance of each collected taxon for each of the four sampling trips is presented in Appendix 5. Taxa restricted to Snowy Creek are identified.

The total number of taxa, the mean number of taxa and the mean number of individuals per sample are shown in Fig. 6.

The total number of taxa increased steadily over the four samples. In August 1981, the tota is comparable to those found at all Mitta Mitta sites and in October 1981, the total is similar to that recorded at site 5. In the two summer samples, the number of taxa greatly exceed those from any of the main river sites. Similar observations can be made for the density of taxa per sample at all four sites in August 1981 ($F = 2.05$, $df = 3, 16$), while by March 1982, site 4C had a significantly higher density of species than any other site ($p < 0.001$ for all comparisons).

From Fig. 5 the samples from Snowy Creek can be divided into distinct summer and winter collections with a high similarity between the two summer samples and a much lower similarity between the two winter samples. Despite the differences in actual species composition this is close to the relationship displayed at site 5 over the same period.

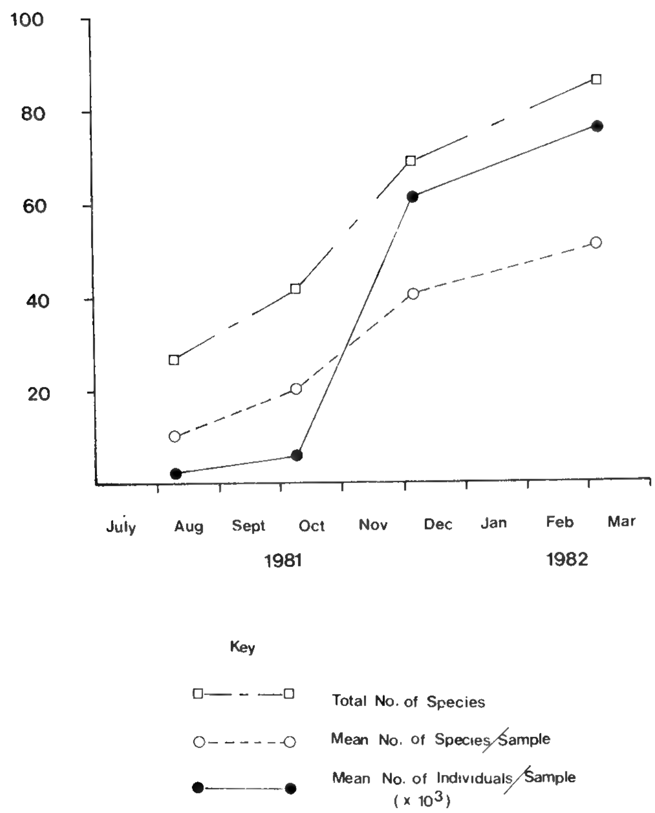

Fig. 6. Total number of species, density of species and density of individuals collected at the sampling site on Snowy Creek during the study.

Faunal distribution

The Biological Survey Department of the Museum of Victoria uses a voucher system for identification of groups for which current taxonomic knowledge is inadequate for species identification. Presumptive 'species,' based on morphological criteria, are identified, described, and designated with a specific code number. Voucher specimens are lodged within this department. Appendix 1 is a complete list of 'species' collected throughout the study, showing the numbering system used.

A total of 163 taxa were identified from the Mitta Mitta River and Snowy Creek during the study period. The majority of the collected taxa (136 species, 83%) belong to the Class Insecta, with representatives from 7 of the 12 common insect orders found in streams (Williams, 1980). The remaining 27 taxa are made up of 18 species of Acarina, one species of Collembolla and 8 nonarthropod invertebrate taxa.

The number of species in each of the seven major insect orders were Ephemeroptera (13 species), Odonata (4), Plecoptera (16), Megaloptera (2), Coleoptera (22), Diptera (49) and Trichoptera (30).

Many of the more common taxa were unevenly distributed between the four sites, presumably reflecting the differences in substratum characteristics, flow regimes and water quality between upstream and downstream sections of the Mitta Mitta River and Snowy Creek (Blyth et al., 1984).

i.Some taxa were distinctly more common at the upstream sites (3A, 4B) of the Mitta Mitta River, being less abundant at both site 5 and Snowy creek (e.g., *Oxyethira collumba*, *Hydroptila* sp.1, *Hydra* spp.).

ii.Other taxa were absent or rare from upstream sites but formed large proportions of the collections at sites 5 and 4C (e.g., Hydracarina sp.42, *Austrolimnius* sp.L10E).

iii.Some taxa were comparatively rare only at the uppermost site 3A, but extremely abundant at other sites (e.g., *Tasmanocoenis* sp.2).

iv.Many taxa were common at all sites on the Mitta Mitta River, but rare or absent in Snowy Creek (e.g., *Physa acuta*, *Isidorella* sp.,*Dinotoperla serricauda*, Tipulidae sp.2, *Cricotopus* sp.1, *Cardiocladius* sp.1).

v.Other taxa were distinctly more abundant in Snowy Creek compared to the main river (e.g., *Atalophlebioides* sp.1, Helodidae sp.1, *Corynoneura* sp.1).

However, the most common taxa were generally the most widespread, forming the dominant proportion of individuals collected at all sites (e.g., Oligochaeta, Hydracarina sp.1, Baetis spp., Austrosimulium furiosum, *Rheotanytarsus* sp.1, *Cheumatopsyche* spp.1 and 2).

In general, the number of taxa collected throughout the entire study increased with increasing distance from the dam, with 70 taxa identified from site 3A, 80 at site 4B and 103 at site 5. This is in direct contradiction to the earliest study (Smith et al., 1978) where upstream sites supported the most diverse fauna. Despite the lower sampling effort utilized, more taxa were collected from Snowy Creek (114) than from any of the Mitta Mitta River sites.

The fauna of slow water

Due to lack of time, less emphasis was placed on sampling and sorting samples from slow waters. In August 1981, no slow water (currents of less than 40 cm sec^{-1}) could be found at site 5 and no slow water samples were collected in October 1981. Specimens collected were only identified to family level or higher.

The total number of higher taxa and the density of taxa and individuals are shown in Fig. 7. Of particular interest was the large increase in the number and density of taxa at both sites 4B and 5 over the irrigation release period, supporting the idea that pool areas and deeper, slow flowing zones act as refuges during times of high flow (Hynes, 1970). Although the density of taxa rose at site 3A, the total number of taxa collected did not increase to the same extent. The gains in taxa immediately following the release were not sustained in later collections at any site.

The higher taxa collected from slow water correspond closely to those from fast water, and, although specimens were not identified to the species level, observations suggest that the dominant species are also common to both current categories. However, areas of slow water seem to contain fewer taxa than areas of fast.

Discussion

Effect of the irrigation release on the benthic macroinvertebrates below Dartmouth Dam

Little work has been reported specifically concerning the effects of large irrigation releases on the downstream macroinvertebrate fauna of regulated rivers. However, the possible effects of such a release can be suggested from studies of similar large natural or artificial changes to the flow rate in a river. Hynes (1970) reviews the effects of sudden spates on benthic invertebrate populations with

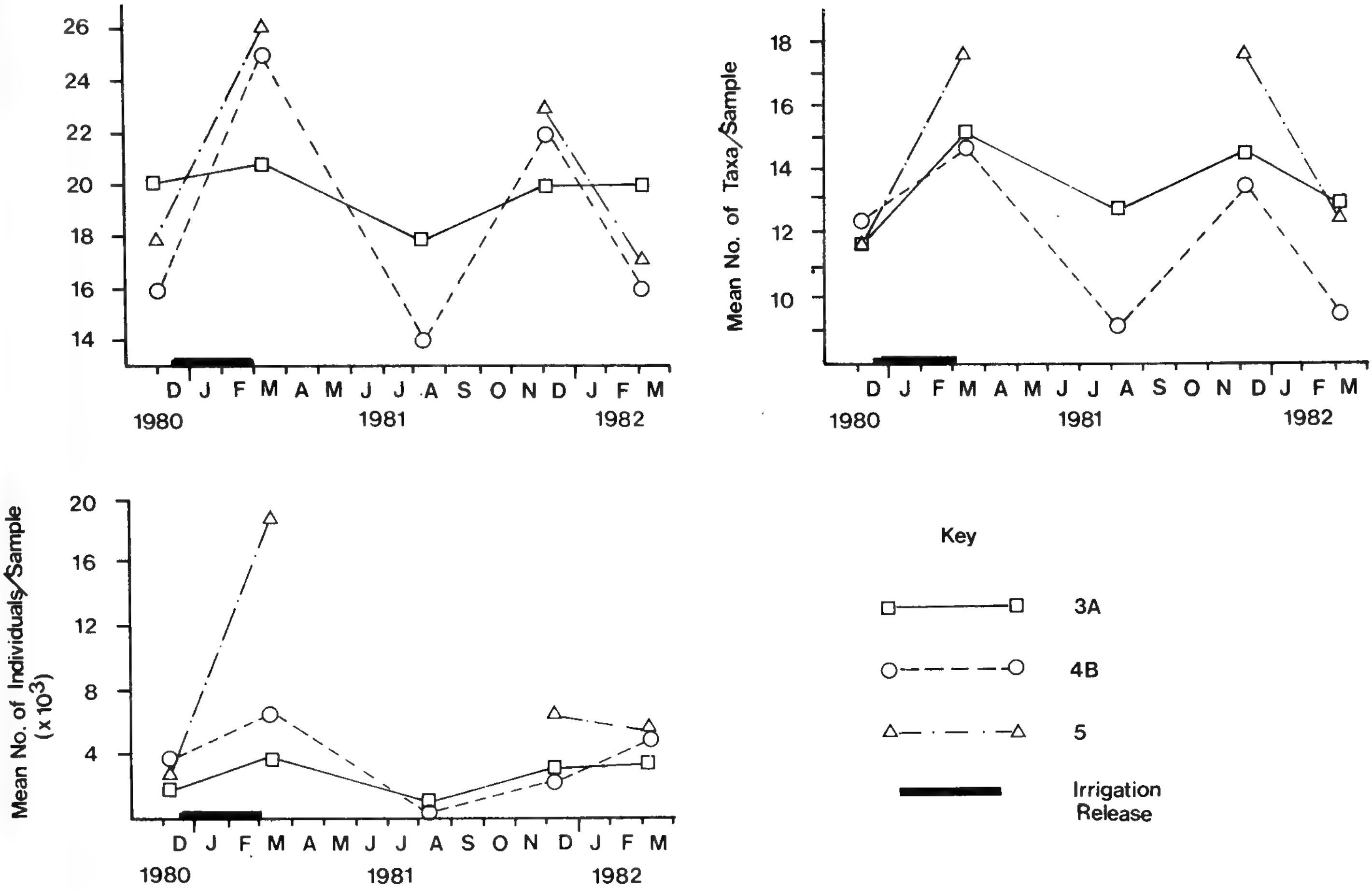

Fig. 7. Total number of taxa, density of taxa and density of individuals collected in slow water samples at each site on the Mitta Mitta River during the study.

the conclusion that there is a rapid decrease in numbers of species and individuals due to the high flow, followed by a period of recolonization once normal flows are re-established. This decrease is presumably a result of the direct removal of animals from the substratum by the scouring action of the high current (Kroger, 1973), of a dramatic increase in the rate of drift (Anderson and Lehmkuhl, 1968; Brooker and Hemsworth, 1978; Radford and Hartland-Rowe, 1979) or the evacuation of animals into refuge areas not subsequently sampled.

Gore (1977) found the same impact of high flows from a reservoir but noted an increase in species diversity further downstream, where animals washed out from upstream reaches were redeposited. During the testing of the Dartmouth Dam outlet tower (short, very high releases), sites close to the dam were severly affected, but with little change downstream (Blyth, unpublished data).

It appears then that the irrigation release had the predicted effect of a sudden spate, reducing the number of taxa at sites close to the source, but having no discernible influence further downstream. At site 3A there was a reduction in the total number of taxa collected from 48 to 37 over the release period while there was no similar reduction at either site 4A or 5.

Many authors have described the rapid recolonization of disturbed habitats with a return to predisturbance levels of species richness (e.g., Townsend and Hildrew, 1976; Williams and Hynes, 1976; Williams, D.D., 1980). Williams and Hynes (1976) examined four mechanisms by which defaunated habitats are repopulated. Drift contributed by far the most significant proportion of colonizing individuals, with other sources being aerial invasion by winged species or ovipositioning by adults, movement across substratum and migration through the interstitial spaces of the substratum.

The sampling programme in this study does not enable the investigation of the immediate recolonization at site 3A. However, there are indications that, for that section of river, the potential for recolonization may be seriously reduced. The reservoir itself constitutes and absolute barrier to drift, and sites immediately downstream of the dam are likely to be more affected than site 3A, further reducing the species pool for downstream drift. The total number of higher taxa and composition of the slow water fauna at site 3A remained relatively constant over the release period (and less diverse than the prerelease fauna in fast water), making it unlikely that the slow zones in the area constitute a significant refuge for species washed out by the high flow rate. The extent of aerial invasion may be reduced by both the lowered diversity in the surrounding habitats and the failure of adults to either emerge or oviposit in the high current. Migration through the substratum is an important potential source of recolinizing individuals, as large numbers of animals are generally found deep in the substratum (e.g., Morris and Brooker, 1979), the hyporheic zone is an important refuge in times

of stress (Hynes, 1974) and the scouring effects of high flows appear only to extend a few centimetres into the stream bed (Beschta and Jackson, 1979; G. Davey, NMV, pers. comm. 1982; own field observations). However, the penetration of the bed by construction sediments and subsequent erosional run-off may have reduced the diversity of fauna capable of surviving deep within the substratum.

The relatively low number of taxa recorded in August 1981 appears to be part of the normal seasonal pattern in the river. Previous winter samples have similar low numbers of taxa (Blyth, unpublished data) and Snowy Creek also displays the same August minimum in number of taxa. It may be unlikely that the distinct elements of winter assemblages (Fig. 5) are influenced by the irrigation release as many of the taxa may be derived from sources unaffected by the high summer flow rate; for example, some taxa may spend summer as diapausing nymphs deep in the substratum, or as eggs securely attached to large rocks (Hynes, 1970).

In the summer samples taken 12 months after the release a substantial change had taken place. Whereas the number of taxa recorded at site 5 returned to near pre-release levels, there was a considerable depression of numbers of taxa at both sites 3A and 4B in comparison to the previous year. In both December 1981 and March 1982, the number of taxa per sample was significantly lower at sites 3A and 4B than at site 5 ($p < 0.01$ and $p < 0.001$ respectively). At all three main river sites, the common taxa during the summer of the irrigation release (members of the Caenidae, Hydropsychidae, Simuliidae, Chironomidae and Hydracarina) are all present during the subsequent summer. However, there appeared to be a general reduction in the number of less common species, over several orders, at the upstream sites. It is not possible to name actual taxa lost, but it would appear that the observed depression of the fauna at sites 3A and 4B represents a real reduction in diversity at those sites.

The reasons behind this reduction in the year following the release are not clear. One of the most obvious explanations is a failure of recruitment of new generation individuals from the adults of the previous year. That is, the irrigation release may have interrupted key elements in the production of offspring by individuals reaching maturity during the summer of 1980/81. Four life cycle events that may have been seriously effected by the release are the emergence of adults, the deposition and hatching of eggs and the subsequent survival of the juveniles. It is conceivable that these events, timed for periods of low flow and high temperatures, could be disturbed by the unnaturally high discharge and temperature depression associated with the release.

Many species undergo significant migrations across the substratum and need to climb vegetation stalks, rocks or banks prior to emergence and these may be eliminated by high flows. Individuals which pupate on the substratum (e.g., Simuliidae) and which must emerge against the current (Hynes, 1970) are also at risk. Oviposition by flying adults required to enter the water, oviposition at the waters edge, with subsequent migration of the larvae into the stream, and eggs dropped directly onto the steam (Hynes, 1970) all stand less chance of survival during the high flow period.

Temperature is responsible for the timing of several life cycle events of many macroinvertebrate species (Hynes, 1970) and relatively small changes in the mean maximum or minimum temperature may be sufficient to significantly disrupt these cycles (e.g., Sweeney and Vannote, 1978; Humpesch and Elliott, 1980). The reduction in temperature (approximately 3°C at Colemans) caused by the release may have been large enough to prevent emergence, hatching or growth of small larvae of some species. The reduction in temperature during the release was additive to the chronic stress due to temperature depression recorded throughout the filling period (Blyth et al., 1984).

At site 3A, there is the additional problem of a possible failure of species to re-establish viable breeding populations immediately after the release. At site 4B, where the scouring effect of the release is not discernible, the flow rate and temperature as discussed above may be the primary cause of the observed later reduction in diversity. The fauna at site 5 is under less stress than further upstream and with a reduced scouring effect of the high flow, higher absolute temperatures and a larger species pool available for recolonization (including many tributaries, slow zones etc.).

Heavy sedimentation of the stream bed during construction eliminated a number of typical mountain stream species, and allowed more widespread groups to proliferate. Both loss of habitat, and excessive drifting by some species as a response to high suspended sediment loads (White and Gammon, 1977) were probably involved in this loss of diversity.

The acute event of dam closure caused rapid death of large numbers of invertebrates by stranding, loss of habitat, premature emergence and catastrophic drift.

The period of filling imposed new conditions of flow, temperature and water quality on the stretch of river between the dam and Snowy Creek and this led to the extirpation of much of the summer-warm component of the fauna, already disadvantaged by the effects of construction. A failure to breed successfully and/or to compete

Critical events in the construction and operation of Dartmouth Dam

The construction and operation of Dartmouth Dam was marked by a series of chronic and acute impacts on the downstream fauna. A detailed account of the faunal changes during construction and the initial filling period was given by Blyth et al. (1984).

Compared to 1974 the fauna collected in the present study in the foothills sections of the study area has undergone a substantial reduction in faunal diversity (fewer taxa present, and a greater degree of dominance by a few of them) and a change in composition. From typical foothill fauna, with a diverse range of species, the effects of construction, impoundment and operation have produced a community dominated by relatively few tolerant species. The typical lowland sites, originally the least diverse have been somewhat less affected and are now higher in diversity than the upstream sites.

It is clear that a number of events related to dam construction and operation have caused both short term and long term impacts upon the invertebrate fauna. While it is not possible to apportion responsibility for particular levels of faunal change to particular events, a sequence of impacts and their likely additive effect can be discerned.

with species better adapted to the altered conditions may be responsible. This effect was most marked at the site closest to the dam with the result that, by 1978, only five taxa were regarded as common, and Oligochaeta and one genus of Chironomidae (*Cricotopus*) composed nearly 90% of the fauna. Sites downstream were not as seriously effected.

Lowland sites appeared to be little influenced by the changed regimes after impoundment with the fauna remaining similar to that found at dam closure. The inflow of several unregulated tributaries and the distance from the dam seems to override the effects of low release, changed temperature patterns and poor water quality recorded further upstream.

The collection made prior to the irrigation release shows that the fauna at all sites on the Mitta Mitta River was characterized by typical lowland species with little difference between reaches upstream or downstream of Snowy Creek. The release itself, discussed previously, continues the trend of eliminating rare species, not fully adapted to the post- impoundment condition, at upstream sites. Species which became dominant in the early stages of construction and impoundment remained unaffected.

Most studies of the environmental impacts of reservoirs have been conducted in the post-impoundment phase, and changes in temperature, flow and water quality have been cited as the major causes for the observed alterations in the invertebrate fauna in the receiving stream (e.g., Hilsenhoff, 1971; Ward, 1974, 1976; Ward and Short, 1978; Ward and Stanford, 1979). In a number of cases (e.g., Ward, 1976) the observed alterations have included reduction of the number of taxa present, and an increase in numerical dominance of Diptera and Oligochaeta. This is the same general change as has occurred in the Mitta Mitta River. However, the major changes to faunal richness and composition observed in this study appear to have occurred or commenced as a result of activities during the construction phase, with post-impoundment conditions contributing to a further decline in the number of taxa present.

Conclusions and summary

This report deals with the impact of the irrigation release made over the summer of 1980/81 upon the benthic macroinvertebrate fauna downstream of the Dartmouth Dam. The hypolimnetic release, of about 8000 Ml day^{-1} for 3 months, produced the predicted effect of a major spate, reducing faunal richness at site 3A (20 km downstream of the dam wall), but having no discernible effect further downstream. However, in the following summer (1981/82), there was a general reduction compared to pre- release levels, in the number of taxa at both sites 3A and 4B (30 km downstream of the dam). This was probably due to the effect of the sustained high flows and depressed temperatures of the release interrupting various stages in the life cycles of summer breeding, rare species, leading to a failure to recruit new generation individuals in the following year. Site 5, 50 km downstream of the dam and below the inflow of Snowy Creek, the major tributary of the Mitta Mitta River, showed no effect of the irrigation release.

The most striking result of this post release study is that the impact on the fauna proved not to be an acute effect followed by a period of recovery, as might have been expected. Although the direct washout effect was very local, the reduction in the fauna continued in the year following the release and extended beyond the range of the immediate impact of the release.

A brief overview of the critical effects of the construction and operation of Dartmouth Dam is also included, indicating that a major part of the observed changes in species diversity and composition can be attributed to the effects of the increased sediment bed load during the construction phase. The most common causes cited as responsible for the deleterious impacts of impoundments (changes to temperature, flow and water quality), seem mostly to continue the elimination of species already disadvantaged during construction.

The future operational plan for Dartmouth Dam involves three distinct phases: an irrigation release, followed by a period of refilling and, if full supply level is reached before the next irrigation release, a period where discharge is essentially unregulated. The effects of the first two phases on the macroinvertebrate fauna are outline in this report and steps could be taken to reduce the deleterious impacts of these procedures. The effect of a period of run-of-the-river release is unknown. If the natural flow regime is established for sufficient time, some recovery (with the re-invasion of previously eliminated species) of the fauna seems possible. Much may depend on the reaction of subsurface sediment to these conditions. There is evidence that unregulated flows, given long periods, remove large quantities of surface sediment (Platts and Megahan, 1975), but the fate of sub-surface fine material is unknown. The extent and maintenance of any faunal recovery recorded during phases of unregulated flow would, to a large extent, depend on the effectiveness of control procedures adopted during the irrigation release and re-filling periods.

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Appendix 1. List of all taxa collected and identified from all sites during the study period showing the voucher system nomenclature used in this laboratory.

Hydrozoa
Hydridae
Hydra spp.
Turbellaria
Dugesiidae
Cura pinguis Weiss
Annelida
Oligochaeta spp.
Bivalvia
Corbiculidae
Corbiculina australis (Deshayes)
Gastropoda
Ancylidae
Ferrissia tasmanica (Tenison-Woods)
Planorbidae
Isidorella sp
Physidae
Physa acuta Draparnaud
Lymnaeidae
Austropeplea lessoni (Deshayes)
Arachnida
Hydracarina sp1E
Hydracarina sp2E
Hydracarina sp3E
Hydracarina sp4E
Hydracarina sp6E
Hydracarina sp7E
Hydracarina sp13E
Hydracarina sp15E
Hydracarina sp33E
Hydracarina sp34E
Hydracarina sp36E
Hydracarina sp42E
Hydracarina sp50E
Hydracarina sp51E
Hydracarina sp52E
Hydracarina sp53E
Hydracarina sp54E
Collembola sp1
Ephemeroptera
Leptophlebiidae
Atalophlebioides sp1
Atalonella sp1
A. sp2
A. sp3
Atalophlebia nr *longicaudata* (sp1)
A. sp6
Baetidae
Baetis sp1
B. sp3
B. sp5
B. sp6
Caenidae
Tasmanocoenis sp2
T. sp3
Siphlonuridae
Coloburiscoides sp1
Odonata
Aeshnidae sp1
Aeshnidae sp2
Gomphidae sp1
Gomphidae sp3
Plecoptera
Eustheniidae
Stenoperla australis Tillyard
Notonemouridae
Austrocercella marianne Illies
Austroperlidae
Acruroperla atra Samal
Gripopterygidae
Eunotoperla kershawi Tillyard
Illiesoperla australis Tillyard
Trinotoperla irrorata Tillyard
T. nivata Kimmins
T. yeoi Perkins
Leptoperla kimminsi McLellan
Riekoperla tuberculata McLellan
R. rugosa (Kimmins)
R. karkireticulata gp
Dinotoperla arenaria Hynes
D. fontana Kimmins
D. serricauda Kimmins
D. brevipennis Kimmins
Megaloptera
Corydalidae
Archichauliodes sp1
A. guttiferus Walker
Coleoptera
Dytiscidae
Rhantus sp1
Hydrophilidae
Berosus sp1
Gyrinidae sp1
Hydraenidae sp1
Helodidae sp1
Psephenidae
Sclerocyphon basicollis Lea
Curculionidae sp1
Elmidae
Kingolus sp1E
K. sp5E
K. sp7E
K. sp38E
K. sp45E
Simsonia hopsoni Carter & Zeck (L4E)
S. spL3E
Notriolus spL57E
Austrolimnius waterhousei Hinton (L34E)
A. spL10E
A. 13E
A. spL14E
A. spL25E
A. spL36E
A. spL62E
Diptera
Tipulidae sp1
Tipulidae sp2
Tipulidae sp3
Tipulidae sp4
Tipulidae sp5
Tipulidae sp9
Empididae sp2
Empididae sp3

Appendix 1. (continued).

Ceratopogonidae
Nilobezzia sp2
Bezzia sp6
Simuliidae
Austrosimulium furiosum Skuse
Simulium ornatipes Skuse
Chironomidae
Orthocladiinae
Eukiefferiella sp1 (2E)
Cordites sp (E)
Thienemanniella sp (10E)
Cricotopus sp1 (12E)
C. sp2 (12BE)
C. sp3 (31E)
Cardiocladius sp (39E)
Corynoneura sp (63E)
nr *Eurycnemus* sp (69E)
Psectrocladius sp (93E)
Symbiocladius sp (102E)
S. sp103E
S. sp117E
S. sp124E
Chironominae
Dicrotendipes sp1 (1E)
D. sp2 (30E)
Rheotanytarsus sp (4E)
Reithia sp (5E)
Cryptochironomus grisiedorsum (Keiffer) (13E)
C. nr *saetheria* sp (15E)
Polypedilum sp (16E)
Calopsectra sp (22E)
Micropsectra sp (50E)
Skusella sp (54E)
Chironomus cloacalis Atchley & Martin (92E)
Chironomus sp (LTCS7)
Parachironomus sp (LTCS2)
P. sp153E
Tanypodinae
Ablabesmyia sp (7e)
Pentaneura sp (32E)
Procladius sp (66E)
P. sp108E
Aphroteniinae
Aphroteniinae sp (18E)
Podonomiinae
Podonomus sp (LTCS1)
Podonomopsis sp (71E)
Trichoptera
Rhyacophilidae
Taschorema sp (sp4)
Ulmerochorema onychion Neboiss (sp11)
Ulmerochorema sp (sp9)
Glossosomatidae
Agapetus sp (sp1)
Hydroptilidae
Orthotrichia atreseta Wells (sp2)
Hellyethira sp (sp4)
Oxyethira collumba (Neboiss) (sp7)
Hydroptila sp (sp11)
H. sp5
Philopotamidae
Hydrobiosella sp (sp1)
Chimarra sp (sp3)
Ecnomidae
Ecnomus sp (sp5)
Polycentropodidae sp5
Hydropsychidae
Austropsyche sp (sp1)
Smicrophylas sp (sp2)
Asmacridea edwardsi (McLachlan) (sp3)
Cheumatopsyche sp1 (sp4)
C. sp2 (sp5)
C. sp3 (sp7)
Helicopsychidae
Helicopsyche sp (sp1)
Conoesucidae sp1
Conoesucidae sp5
Conoesucidae sp9
Conoesucidae sp10
Conoesucidae sp13
Calamoceratidae
Anisocentropus sp (sp)
Philorheithridae sp2
Leptoceridae
Notalina bifaria Neboiss (sp6)
N. fulva Kimmins (sp17)
N. sp4

Appendix 2. Mean abundance (individuals per sample) of each taxon collected and identified in fast water at Site 3A over the study period.

	1.12.80	2.3.81	6.8.81	7.10.81	2.12.81	4.3.82
Oligochaeta	308	272	110	68	52	420
Cnidaria						
Hydra spp..	40	2	30	82	48	34
Platyhelminthes						
Cura pinguis	2					
Mollusca						
Corbiculina australis	2				20	12
Physa acuta	8	4				
Isidorella sp.	2	2				
Physidae/Planorbidae unid.		12				2
Ferrissia tasmanica			2			
Arachnida						
Hydracarina sp1E	62	18	28	30	20	12
sp13E				4	2	4
sp33E	2					
sp42E		2	4	4		
sp50E	2			2	40	4
sp51E	2					6
sp52E	6	2	8	8	8	2
UID		4	4	2		2
Insecta						
Ephemeroptera						
Baetis sp1		6				
sp3	2	12				
sp6	8	14	4			40
UID	12	84			12	12
Tasmanocoenis sp2	40	22			12	16
sp3				2		
Coloburiscoides sp1		18				
Odonata						
Gomphidae sp3	1					
Plecoptera						
Illiesoperla australis		20	6	8	2	
Riekoperla karki-reticulata			14			
Dinotoperla fontana			2	2		
D. serricauda	64	30	310	196	2	
Dinotoperla sp. unid.		10				
Megaloptera						
Archichauliodes guttiferus	8				2	
Coleoptera						
Rhantus sp.					2	
Sclerocyphon basicollis	2					
Elmidae sp5E	2					
sp10E		2		2	4	4
sp45E	4					
sp62E	2					
unid.	4					2
Adults	2				4	
Diptera						
Tipulidae sp2	20	2			20	4
Empididae sp3			4	4	18	

Appendix 2. (continued).

	1.12.80	2.3.81	6.8.81	7.10.81	2.12.81	4.3.82
Ceratopogonidae sp2						2
Austrosimulium furiosum	28	2440	106	202	1464	198
Simulium ornatipes					4	
Chironomidae sp1E					2	6
sp2E	6	2	10		12	8
sp4E	22	2	38	2	544	176
sp5E	34		2		8	44
sp7E						6
sp9E	6	2				
sp10E	22		8	40	64	
sp12E	154	24	18	6	74	8
sp12BE	68	4	28	6	44	30
sp15E					2	
sp16E						24
sp22E	8				82	56
sp30E	2					2
sp31E	4	10	6	2		2
sp33E	12	2				
sp39E	14	162		6	24	
sp66E	4	2			2	
sp70E	6	2	2			
sp93E						96
sp108E	2					
unid.	72	6		8		18
Trichoptera						
Rhyacophilidae sp4		4				
sp9	2	10	2			
unid.				4	4	2
Hydroptilidae sp7	42		10			6
sp11	70	2	6	2	56	10
unid.		8				6
Ecnomidae sp5	38	2	8	28	152	470
Polycentropodidae unid.	4	6				
Hydropsychidae sp2	6	2			4	
sp3	8		2		12	
sp4	336	166	20	12	64	8
sp5	192	558	10	10	144	16
unid.	2656	2258			768	118
Conoesucidae sp10		2				
sp13						
unid.	4				4	2
Leptoceridae spA						
sp17		2				

Appendix 3. Mean abundance (individuals per sample) of each taxon collected and identified in fast water at Site 4B.

	2.12.80	12.3.81	7.8.81	7.10.81	2.12.81	4.3.82
Oligochaeta	968	914	344	136	334	770
Cnidaria						
Hydra spp.	24	2	4	12	20	6
Platyhelminthes						
Cura pinguis	4					
Mollusca						
Corbiculina australis)		6		4	20	12
Physa acuta	192	10				
Isidorella sp.	154	2				
Physidae/Planorbidae unid.	252	12				4
Ferrissia tasmanica	78				4	
Austropeplea lessoni	76					
Arachnida						
Hydracarina sp1E	24	172	14	20	356	342
sp2E	2	4			10	4
sp13E		14			16	12
sp15E	14	8	6	6	8	4
sp33E	4					
sp36E		2				
sp42E	2	12				
sp50E	32	4		16	12	2
sp51E	18	4			16	8
sp52E	46	34		6	42	86
unid.	16	56	18	4	52	4
Insecta						
Ephemeroptera						
Atalonella sp. unid.		10	2			
Baetis sp1		6				
sp3		8			4	
sp5	2					
sp6	8	74				34
unid.	2	228		6	14	46
Tasmanocoenis sp2	748	520	112	76	490	4156
sp3	10			14	6	82
Coloburiscoides sp1	2	14			20	
Odonata						
Gomphidae sp3	6	6		4		5
Plecoptera						
Acruroperla atra				2		
Illiesoperla australis		16	2			
Trinotoperla irrorata		2				
Riekoperla karki-reticulata			4			
Leptoperla kimminsi			2			
Dinotoperla fontana			4			
D. serricauda	6	20	314	92	4	
Dinotoperla sp. unid.		28				
Megaloptera						
Archichauliodes guttiferus		2			10	
Coleoptera						
Rhantus sp.	4					
Sclerocyphon basicollis	2					
Helodidae sp1	2					

Appendix 3. (continued).

	2.12.80	12.3.81	7.8.81	7.10.81	2.12.81	4.3.82
Elmidae spL10E					10	14
spL45E	2					
spL62E		2				
unid.	4	2				2
Adults	4	2			4	12
Diptera						
Tipulidae sp2	8	14			14	6
Empididae sp2			4	2	4	
sp3	18	2	6		12	2
Ceratopogonidae sp6	2	2				
Austrosimulium furiosum	2	4738		34	244	480
Simulium ornatipes						12
Chironomidae sp1E						12
sp2E	2	4	10	20	66	8
sp4E	28	16	80	88	228	166
sp5E	64		4		2	124
sp9E	4	8				
sp10E	2	18	8	56	36	16
sp12E	54	210	2	28	74	32
sp12BE	24	58	32	18	54	14
sp16E	4	4			2	6
sp22E	94	10			58	72
sp30E	2					6
sp31E		196			26	4
sp33E		8				
sp39E		412		2	10	8
sp50	2					
sp63		2				2
sp66E	4	2	2		2	
sp70E	4					
Tricoptera						
Ryacophilidae sp11		2				
Glossosmotadae sp1		2	4			
Hydroptilidae sp4					2	
sp7	6		8	12	8	2
sp11	14	4	4	14		10
unid.		18		10	4	14
Philopotamidae sp3	2					
Ecnomidae sp5		4	6	2	68	336
Polycentropodidae unid.		6				
Hydropsychidae sp2						2
sp4	78	180	4	2	16	40
sp5	112	528	16		104	106
unid.	204	2660			154	956
Conoesucidae sp10		2				
sp13		2				
unid.	4				6	
Leptoceridae unid.		12				

Appendix 4. Mean abundance (individuals per sample) of each taxon collected and identified in fast water at site 5 over the study period.

	1.12.80	13.3.81	7.8.81	8.10.81	3.12.81	5.3.82
Cnidaria						
Hydra spp.	6			4	8	4
Platyhelminthes						
Cura pinguis	8	8		2		36
Oligochaeta	1474	542	350	686	774	220
Mollusca						
Corbiculina australis		2				
Physa acuta	6	6				
Isidorella sp.	8					
Physidae/Planorbidae unid.	22					4
Ferrissia tasmanica						4
Arachnida						
Hydracarina sp1E	388	480	6	40	142	934
sp2E	4	10			18	10
sp7E					8	
sp13E	6	92			32	8
sp15E	18	4	2	4	8	8
sp33E	42	24	2	6	74	110
sp42E	18	182		6		36
sp50E	22	6		4	6	4
sp51E	104	2			20	
sp52E	716	42	18	12	20	160
unid.	134	56	6	8	56	50
Collembola	2					
Insecta						
Ephemeroptera						
Atalophlebioides sp1	2	2	2	10	38	
Atalonella sp1				4		
sp2					2	2
sp3					12	
unid.		2		6	8	
Baetis sp1	2	6				
sp3	10	10	2		48	
sp6	2	54	2	2	38	192
unid.	38	256	4	8	156	394
Tasmanocoenis sp2	4262	1778	62	70	584	7192
sp3	32		4	4	8	104
Coloburiscoides sp1	6	110	4	2	12	6
Odonata						
Gomphidae sp3	18	1			11	23
Aeshnidae sp1		1				
Plecoptera						
Illiesoperla australis	2	28	4	4		
Riekoperla karki-reticulata			8	18		
Dinotoperla brevipennis				1		
Dinotoperla fontana			2	2		
D. serricauda	20	4	246	91	9	
Dinotoperla sp. unid.		14				
Megaloptera						
Archichauliodes guttiferus	1					
Coleoptera						
Rhantus sp.		4				
Sclerocyphon basicollis	2					
Curculionidae sp1			2			

Appendix 4. (continued).

	1.12.80	13.3.81	7.8.81	8.10.81	3.12.81	5.3.82
Hydraeindae sp1				2		
<u>Berosus</u> sp.						2
Gyrinidae sp1						4
Elmidae spL4E				2		
spL5E						2
spL7E						2
spL10E	16	42	6	12	110	148
spL14E		4				
spL34E						12
spL38E	2					
spL45E						2
spL62E			2			
unid.	12	8				46
Adult	6	90		6	28	28
Diptera						
Tipulidae sp2	42	16		2	44	
sp3			2			
sp5	2					
sp10		2			2	
Empididae sp2		2			6	2
sp3		6	12		64	2
Ceratopogonidae sp2			12			
<u>Austrosimulium furiosum</u>	22	1856	56	88	298	532
<u>Simulium ornatipes</u>						2
Chironomidae sp1E						4
sp2E	14		6	14	128	6
sp4E	26	52	2	76	444	54
sp5E	10			2	22	8
sp7E				2		4
sp9E		2		2	2	
sp10E	6	28	2	70	192	24
sp12E	186	112		128	140	10
sp12BE	40	82		8	32	16
sp15E					14	
sp16E				8		2
sp22E	16	2		2	22	60
sp30E						8
sp31E		30				2
sp33E		10				4
sp39E	6	266	2	2	42	8
sp63E					4	36
sp66E	12			2	2	2
sp70E	10			22	12	
sp92E		2				
sp93E				2		
sp103E				2		
sp108E					2	376
sp124E					4	2
sp153E				2		
unid.	20	6	2		84	38
Trichoptera						
Rhyacophilidae sp11					2	
unid.				2	12	
Glossosomatidae sp1				2		

Appendix 4. (continued).

	1.12.80	13.3.81	7.8.81	8.10.81	3.12.81	5.3.82
Hydroptilidae sp7	6					
sp11	4					6
unid.		6			2	4
Philopotamidae sp1	2					
Ecnomidae sp5					2	282
Polycentropodidae unid.	2	2				
Hydropsychidae sp1		2				
sp2		2				
sp3						2
sp4	286	388	2	4	54	154
sp5	512	1786	14	28	1678	480
unid.	1918	9904			2934	590
Conoesucidae sp9				2		
sp13			2			
unid.	4	10			84	
Philorheithridae sp2		4				
Leptoceridae sp4	4					
sp6		2				
sp17						
unid.	2				18	26

Appendix 5. Mean abundance (individuals per sample) of each taxon collected and identified at Site 4C over the study period.
* - species found only in Snowy Creek

			6.8.81	9.10.81	2.12.81	4.3.82
Oligochaeta			28	94	740	560
Arachnida						
Hydracarina		sp1E		2	70	208
		sp2E			4	22
	*	sp3E			2	2
	*	sp4E			10	24
	*	sp6E			6	
		sp7E			6	6
		sp13E		4	56	6
		sp15E	2			2
		sp33E				8
	*	sp34E		2	20	36
		sp36E			2	14
	*	sp37E			2	
		sp42E	2	12		446
		sp50E			2	2
		sp52E	2	2	4	16
	*	sp53E		2		4
	*	sp54E			2	4
		unid.	2		122	34
Insecta						
Ephemeroptera						
Atalophlebioides		sp1	30	66	134	224
		unid.	2		232	396
Atalonella		sp1				
		sp2			2	70
		sp3			6	
		unid.		36	12	
Atalophlebia	*	sp1				4
	*	sp6				2
Leptophlebiidae		unid.		4		
Baetis		sp1			14	
		sp3		4	130	150
		sp6				28
		unid.		4	84	152
Tasmanocoenis		sp2	8	8	12	118
Coloburiscoides		sp1	1		28	42
Odonata						
Aeshnidae	*	sp2				2
Gomphidae	*	sp1	1			
		sp3		4	11	
		unid.				8
Plecoptera						
*Stenoperla australis					2	2
*Austrocercella marianne				4		
*Eunotoperla kershawi						1
Illiesoperla australis				6	8	8
Trinotoperla irrorata			4			
*T. nivata						2
*T. yeoi				6		

Appendix 5. (continued).

			6.8.81	9.10.81	2.12.81	4.3.82
*Reikoperla tuberculata					2	
*R. rugosa				4		
R. karki-reticulata			8	4		
*Dinotoperla arenaria			2		6	
D. serricauda					10	6
Dinotoperla sp		unid.	4			
Gripopterygidae		unid.		2		
Megaloptera						
*Archichauliodes		sp1	2			
A. guttiferus						8
Coleoptera						
Helodidae		sp1			10	88
		unid.			20	
Elmidae	*	spL1E			2	
	*	spL3E		2		4
		spL4E		2	12	12
		spL5E			2	
		spL7E				10
		spL10E	34	62	380	598
	*	spL13E			3	52
	*	spL25E				12
		spL34E				2
	*	spL36E			2	4
	*	spL57E			2	
		spL62E			4	46
		Adult	2	4	92	134
		unid.				294
Diptera						
Tipulidae	*	sp1				1
		sp3				4
	*	sp4		8	6	70
		sp10				2
Empididae		sp2			26	6
		sp3		2	136	16
Ceratopogonidae		sp2			2	8
		unid.			2	
Austrosimulium furiosum		6	78	550	186	
Chironomidae		sp2E			10	4
		sp4E	14	36	1928	136
		sp5E	2	2	78	50
		sp7E			16	
		sp9E	4	12	16	24
		sp10E	4	30	1500	58
		sp12E		12	26	
		sp13BE	2	6	50	12
	*	sp13E			2	
		sp15E	2		4	8
		sp16E		2	42	2
	*	sp18E	2		14	6
		sp22E			4	20
	*	sp32E		2		
		sp39E			10	6
	*	sp54E		2		

Appendix 5. (continued).

			6.8.81	9.10.81	2.12.81	4.3.82
		sp63E			216	130
		sp66E				32
	*	sp69E				2
		sp70E	2	14	90	22
	*	sp71E		2		
	*	sp102E				2
		sp108E		2		12
	*	sp117E		2	2	
		sp124E		12		
	*	spLTCS1	2	16		
	*	spLTCS2		2		
	*	spLTCS6			2	
		unid.	2	4	166	60
Trichoptera						
Rhyacophilidae		sp4			2	1
		sp9			2	
		unid.			2	2
Glossosomatidae		sp1	2	8	30	20
Hydroptilidae	*	sp2				4
	*	sp5			6	20
		sp7			2	4
		unid.	1		2	8
Philopotamidae		sp3				2
		unid.			4	
Ecnomidae		sp5				2
Hydropsychidae		sp4				10
		sp5	2		6	594
	*	sp7				2
		unid.		2	142	752
Helicopsychidae	*	sp1			4	
Conoesucidae	*	sp1			2	
	*	sp5				10
		sp10				30
	*	sp11		2		
		sp13		2		
	*	sp14	2			
		unid.			22	6
Calamoceratidae	*	sp1			2	14
Philorheithridae		sp2			2	
Leptoceridae		sp6			56	4
		sp17		8	24	12

Appendix 6. Mean abundance (individuals per sample) of each taxon collected and identified in slow water at Site 3A over the study period.

	1.12.80	12.3.81	6.8.81	2.12.81	4.3.82
Cnidaria					
Hydridae	98	2	30	142	116
Oligochaeta	794	278	66	266	1134
Mollusca					
Corbiculidae	418	106	60	164	36
Physidae/Planorbidae	50	2			
Physidae	6				
Limnaeidae	6				
Arachnida					
Hydracarina	10	102	32	132	30
Insecta					
Ephemeroptera					
Leptophlebiidae	2				2
Baetidae	2	98	2		2
Caenidae	10	28	8	52	18
Siphlonuridae				12	2
Odonata					
Gomphidae	2	8		4	2
Plecoptera					
Gripopterygidae	2	44	154		2
Megaloptera					
Corydalidae			2		
Coleoptera					
Hydrophilidae		6	2	2	24
Gyrinidae					2
Elmidae (larvae)	2	2		2	
(adults)		2		6	
Diptera					
Tipulidae		14		6	2
Empididae		2	14	12	
Ceratopogonidae	38	4	8		6
Simuliidae		496		22	6
Chironomidae	230	392	206	1570	1538
Trichoptera					
Hydroptilidae	14	92	22	92	28
Ecnomidae	12	18	34	138	516
Polycentropodidae				2	
Hydropsychidae	12	2020	14	230	42
Conoesucidae		2		6	
Leptoceridae	18		6	2	10

Appendix 7. Mean abundance (individuals per sample) of each taxon collected and identified in slow water at Site 4B over the study period.

	1.12.81	12.3.81	6.8.81	2.12.81	4.3.82
Cnidaria					
Hydridae	124	4	4	106	10
Platyhelminthes		2	2		
Oligochaeta	1370	612	132	138	998
Hirudinea	2				
Mollusca					
Corbiculidae	6	2			2
Physidae	26	2			
Physidae/Planorbidae	162	10			2
Limnaeidae	16				
Ancylidae				6	
Arachnida					
Hydracarina	76	28	122	184	50
Insecta					
Ephemeroptera					
Leptophlebiidae	2	2			
Baetidae		372			
Caenidae	312	460	60	638	1234
Siphlonuridae		8		8	
Odonata					
Gomphidae		1		2	2
Plectoptera					
Gripopterygidae		140	56		
Megaloptera					
Corydalidae		1			
Coleoptera					
Hydrophilidae		2		2	
Elmidae (larvae)			2	4	
(adult)				8	
Diptera					
Tipulidae		14		4	
Empididae		8	12	18	2
Ceratopogonidae	4		2	2	10
Simuliidae		1070	2	10	6
Chironomidae	1562	1598	126	1386	2922
Tricoptera					
Glossosomatidae		2			
Hydroptilidae	16	130	8	16	16
Ecnomidae		4	16	84	228
Hydropsychidae	28	2042		48	20
Conoesucidae		2		6	
Leptoceridae	16			2	

Appendix 8. Mean abundance (individuals per sample) of each taxon collected and identified in slow water at Site 5 over the study period.

	2.12.81	13.3.81	3.12.81	5.3.82
Cnidaria				
Hydridae			4	2
Platyhelminthes	2	8		
Oligochaeta	224	166	1304	16
Hirudinea	2			
Mollusca				
Corbiculidae		12		
Physidae/Planorbidae	94	4		18
Physidae		2		
Acarina				
Hydracarina		870	392	140
Collembola	2			
Insecta				
Ephemeroptera				
Leptophlebiidae	2	10	36	
Baetidae	2	216	222	70
Caenidae	1416	4672	984	2044
Siphlonuridae		40	6	
Odonata				
Gomphidae	2	26	6	18
Plecoptera				
Gripopterygidae	2	46	8	
Megaloptera				
Corydalidae			4	
Coleoptera				
Psephenidae		6	2	
Elmidae (larvae)		64	52	30
(adult)		42	2	
Diptera				
Tipulidae		46	24	2
Empididae	10	8	56	
Ceratopogonidae	12	2	4	2
Simuliidae		122	28	2
Chironomidae	726	858	1420	1706
Trichoptera				
Glossosomatidae			4	
Hydroptilidae	46	26	14	22
Ecnomidae	6	2		386
Hydropsychidae	40	10222	1956	122
Conoesucidae		20	120	
Leptoceridae	14	12	16	4

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Chemical and physical features of construction sediment in the Mitta Mitta River, Victoria

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Abstract. West, G., Blyth, J.D., Balkau, F., and Slater S. (1984) Chemical and physical features of construction sediment in the Mitta Mitta River, Victoria. *Occ. Pap. Mus. Vict.* 1: 129–38.

The extent, physical structure, and composition of sediment layers on individual cobbles were examined in riffle areas of the Mitta Mitta River upstream and downstream of the Dartmouth Dam construction site. Significantly greater total mass and organic weight were present at two sites 2 and 10 km downstream of the construction site than at upstream sites. Average chlorophyll a levels below the dam were up to 87 times that at an upstream site. The surface material showed alternating layers of inorganic sediment and plant material, presumably related to the occasional influxes of sediment following heavy rainfall. Regular water quality monitoring during the construction period showed significant increases below the construction area in turbidity and suspended solids, but not in total P, N, TKN or silica. It is suggested that algal (and cyanobacterial) species are capable of directly using nutrients adsorbed to inorganic sediment. The need for water quality monitoring relevant to biological events within streams is stressed.

Introduction

Sedimentation of stream beds has been observed as a result of dam construction (Eustis and Hillen, 1954; Grenney and Porcella, 1976; Blyth and St Clair, 1978), forestry activity (Tebo, 1955; Anderson, 1971; Graynoth, 1979), and road construction (Anderson 1971; Barton, 1977; Lenat et al., 1981). The adverse effect of such sedimentation on stream invertebrates (Ellis, 1936; Cordone and Kelly, 1961; Chutter, 1969; Graynoth, 1979; Blyth et al., 1984), and on fish (Tebo, 1955; Cordone and Kelly, 1961; Phillips, 1971; Cadwallader, 1978) is also well documented.

Construction of Dartmouth Dam on the Mitta Mitta River in north Eastern Victoria commenced in 1972, and monitoring studies on invertebrate communities in the river started in February 1974 (Smith et al., 1977, 1978; Blyth et al., 1984). From 1976 onwards the monitoring study reported obvious sedimentation of the substratum downstream of the construction area, and changes in benthic communities (Blyth and St Clair, 1978; Blyth, 1980; Blyth et al., 1984). As a result of these observations, this study was instituted to examine directly some aspects of input, type, and physical structure of stream sediment. Results were reported elsewhere (EPA, 1980). However, circulation of that report was limited, and presentation of the main results and discussion in the light of the other Dartmouth studies is of considerable value in this volume. The major aim of this paper is to describe the extent, physical structure, composition, and chemistry of any sediment layer in riffle areas upstream and down stream of the construction site, and to compare these with material from potential source areas. In addition, the observations on bed material are compared with the results of routine water quality monitoring throughout dam construction (Graham et al., 1978).

Study area

The study area (Fig. 1) is described in broad terms in Blyth et al. (1984) and more details regarding working procedure and erosion control methods were provided in EPA (1980).

The rock types in the project area are granitic gneiss in the immediate dam site area, and granite upstream and down stream of this section. Soils derived from such parent rocks are considered to be highly erodible (Boughton, 1970). Gorge slopes at the dam site were about 35° on the northern wall, and 20–25° on the southern wall, with slopes in the lower 60–100 m locally up to 10° steeper (Snowy Mountains Engineering Corporation, 1975). In the area of the dam site and spillway-cascade, a total area of about 110 ha was cleared by dozing and chain saw felling. Preparation of works areas required several large gullies near the dam site to be filled.

Work on the upstream and downstream portals of the

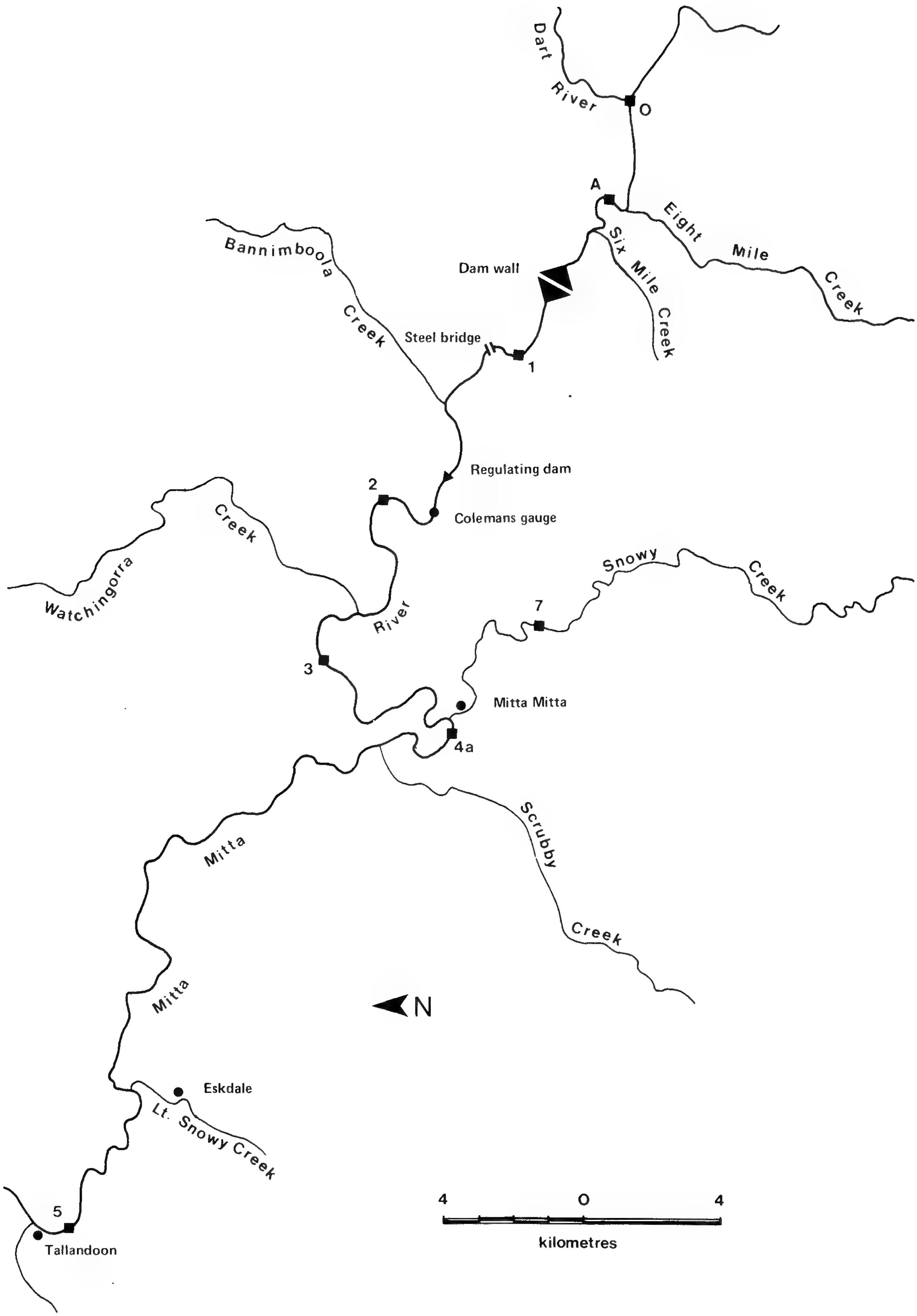


Fig. 1. Map of study area.

diversion tunnel commenced in 1973 and considerable instability of the batters, made worse by heavy rains, was experienced. During the wet months of August to October 1974, slips occurred in both cut and fill batters as a result of inadequate drainage allowing saturation of the material. Although point sources of sediment were subject to licencing procedures, and were discharged through a settling pond, diffuse runoff was the major factor in the movement of soil into the river.

Sampling sites (Fig. 1) were described by Blyth et al. (1984). An additional two control sites above the dam area (sites A and O) were used and site 5 at Tallandoon was deleted.

Methods

Quantitative assessment of algal-sediment deposits was made by removing cobbles at random from the riffle area and scraping or brushing any deposit from a measured area of the upper surface into a polyethylene container. Riffle areas at each site were selected to be as similar as possible in terms of substratum type (basically boulders, cobbles and pebbles), current (0.3–0.9 m sec^{-1}), and depth of water (0.2–0.9 m). Bed sampling was carried out once only, in November 1977. The resulting sediment samples (10 from each site) were dried at 105°C for 24 hours then reweighed after heating at 580°C for 2 hours. The loss of weight on ignition was used as a measure of the organic material.

Chlorophyll analysis was carried out on four fresh samples from each site, using a spectrophotometric method described in American Public Health Association (1976). Results for chlorophyll a, which gives an indication of the amount of living material present, and phaeophytin a, its breakdown product, were obtained.

An investigation of the mineral composition and particle shape and size of sediment deposits in the river below the dam was carried out to determine whether distinctive features could be found which were attributable to construction activity. Samples of dried algal-sediment material, collected after exposure of much of the river bed following commencement of storage, were examined using light microscopy.

Since most of the surface-chemical and ion-exchange activity of soils is associated with the clay and humus fractions, the types of clay mineral present in the algal-sediment deposits collected from below the dam were investigated. The composition of the clay fraction was analysed using X-ray diffraction.

Analysis for biologically extractable nutrients of soil and bed sediments was carried out by the Division of Agricultural Chemistry using conventional methods from the Chemical Methods Manual, Department of Agriculture, Victoria. Soil samples were collected in the borrow area and erosion gullies, and sediment samples were collected from the river below erosion gullies. Each sample consisted of a composite of 20 cores, each 10 cm deep. The algal-sediment samples were from the same sites as sampled for the particle-size analysis.

Sediment particles may transmit sorbed substances from soil to water, or may provide active surfaces for sorption of dissolved substances from water. To investigate this aspect of nutrient exchange, soil leaching tests were carried out. Soil samples from the borrow area and from an erosion gully 2 km below the dam, and an algal-sediment sample from site 1, were tested. Samples were dried and sieved through a 2 mm Nalgene plastic sieve. Then 0.4 g of the sieved material was added to 80 ml of distilled water in a 10 ml polypropylene centrifuge tube (solution:soil ratio of 200:1), and shaken for approximately 20 hours at room temperature. Analyses for soluble reactive silicon, nitrate and nitrite, and orthophosphate were carried out on the supernatant following centrifugation, using methods from 'A Guide to the Sampling and Analysis of Water and Waste Water: EPA Victoria' for silicon, nitrate and nitrite, and from Grigg (1975) for orthophosphate.

A water quality monitoring programme was commenced in February 1974 by the State Rivers and Water Supply Commission, and encompassed a considerable number of indicators at 24 sampling points along the Mitta Mitta River and its tributaries (Graham et al., 1978). Data on turbidity and suspended solids (daily and monthly readings) for four sites were made available for this study. Sampling sites were upstream of the influence of earthworks, immediately downstream of the diversion tunnel outlet, at the steel bridge, and at Colemans gauge (Fig. 1).

For this study it was intended to monitor the levels of nutrients during periods of high turbidity. Lack of rain prevented monitoring of storm events but sampling was carried out during periods of high turbidity associated with the closure of the dam. Analyses were carried out for total phosphorus, ammonia, nitrate, and soluble reactive silicon. Methods used were from 'A Guide to the Sampling and Analysis of Water and Waste Water; EPA of Victoria."

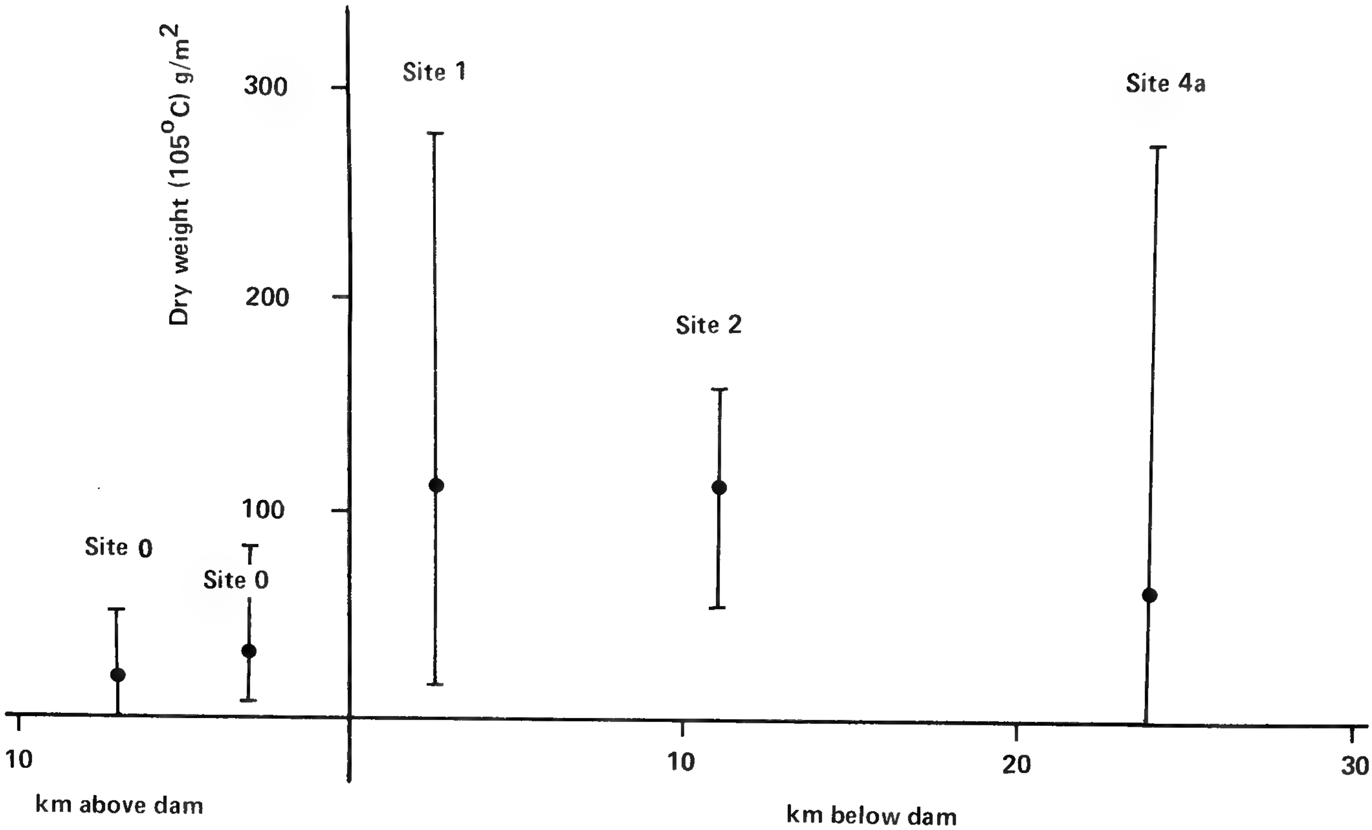
Results

Quantitative sampling of algal-sediment layer on cobbles

Mass of sediment/algae. The most noticeable features of the results were the much greater amounts of algal-sediment material on cobbles below the dam, and the high organic content of the material (Fig. 2). The results based on total dry weight (Fig. 2a) showed that average levels at sites below the dam were up to six times a high as that at site O, and nearly four times as high as that at site A. A Kruskal-Wallis test for independent samples (Sokal and Rohlf, 1969) indicated significant differences between sites ($p < 0.01$), but did not show between which particular sites significant differences existed.From this the simultaneous test procedure described in Sokal and Rohlf (1969) was used and showed that significant differences existed between the upstream sites and the two closest downstream sites ($p < 0.01$). No significant differences were apparent between the two upstream sites or among the three downstream sites.

The differences between upstream and downstream sites are highlighted when organic weight (g m^{-2}) is considered (Fig. 2b), the average levels at sites below the dam being up to 13 times the level at site O. Visual inspection of the samples from below the dam site indicated that algal material and not detritus could be expected to account for most of the organic matter.

Chlorophyll analysis. These results (Fig. 3) showed a considerable increase in average levels of chlorophyll a at sites below the dam, with the highest levels found at site 2. This was the same pattern shown by the results of the or-



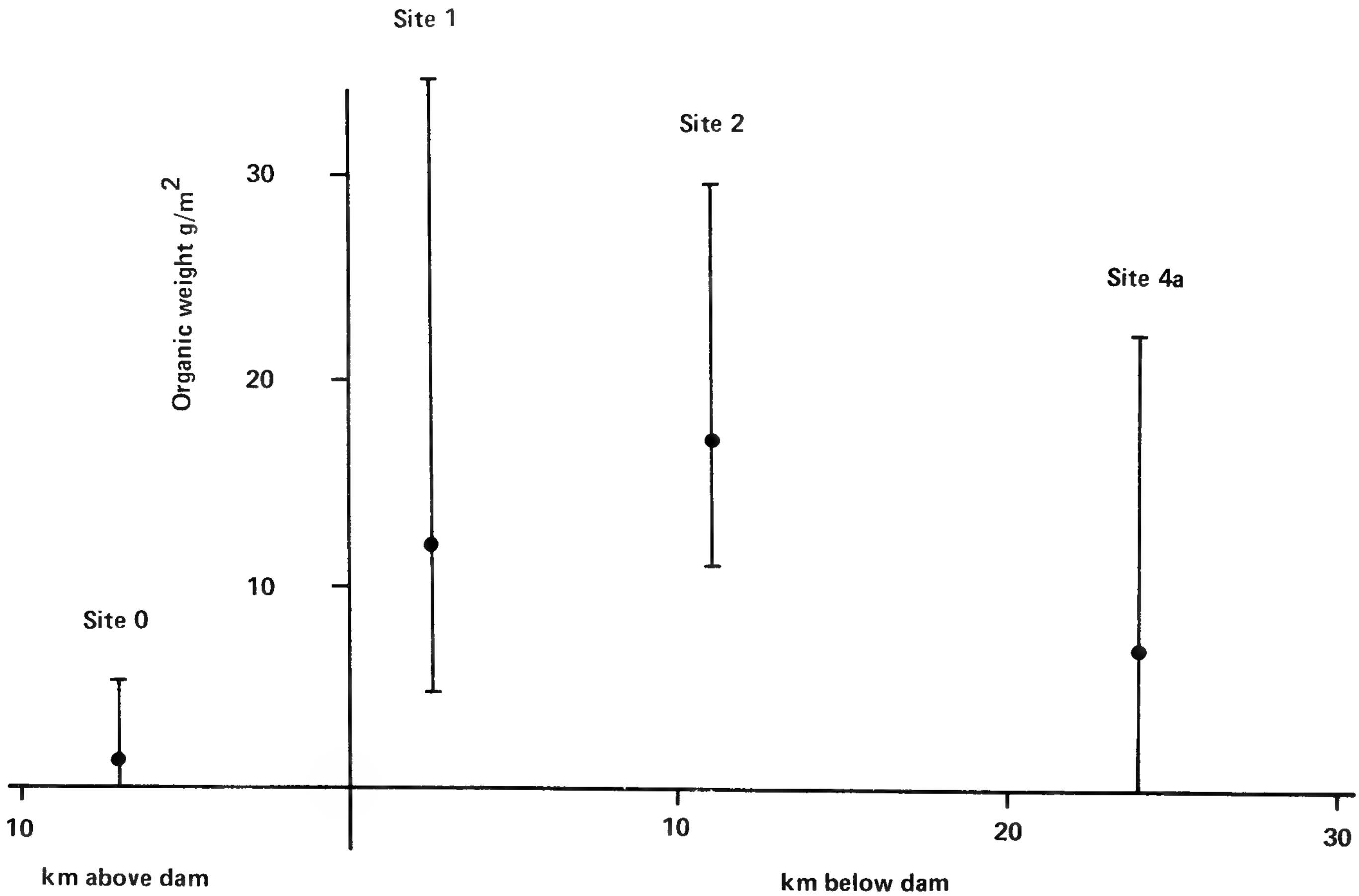


Fig. 2. Dry weight (top) and total weight (bottom) of organic material at five sites in the Mitta Mitta river. Means and ranges are given.

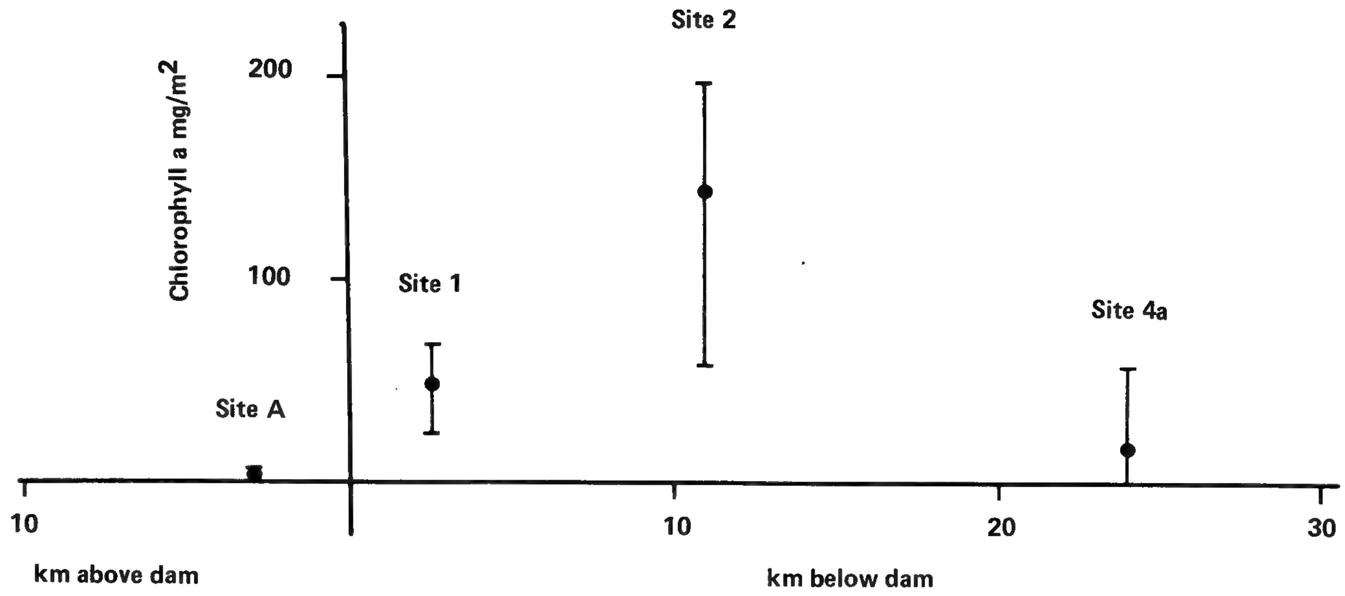


Fig. 3. Concentrations of chlorophyll a at four sites in the Mitta Mitta River. Means and ranges are given.

ganic weight analysis. The relative increase in chlorophyll levels was, however, much higher than that for the organic weigh analysis. Average chlorophyll a levels below the dam were up to 87 times those of the upstream site. A KruskalWallis test showed significant differences ($p < 0.01$) between the four sites (upstream site A, and downstream sites 1, 2 and 4a). Because of the small sample size no attempt was made to test between which particular sites significant differences existed.

Results for phaeophytin were equivocal, showing great variability, and are not presented here.

Structure and mineral composition of the algal-sediment layer. The sediment layers from the river cobbles showed a distinctly layered structure with the alteration of layers of plant matter and sediment particles (Department of Minerals and Energy, pers. comm.). The latter ranged in size from fine sand to clay sized particles with fine sand (0.125–0.25 mm) and silt (0.004– 0.063 mm) predominating, and sometimes appeared to be graded. The structure suggested that sediments were deposited layer by layer over a period of time, each layer representing a fresh influx of sediment.

The mineral composition of the sand fraction of the samples from the site of the regulating dam and site 2 was consistent with a granitic provenance (Table 1). Grains were highly angular to sub-rounded; feldspar grains were fresh to moderately weathered. In general, grain size and shape were not unusual, though there was some sharp material that could have been due to construction activity.

X-ray diffraction studies revealed the presence of the following clay minerals at the two sites samples:

Clay Mineral	Regulating dam site	site 2
Illite	abundant	abundant
Kaolinite	trace	trace

Analysis of nutrients in soil and sediment layers. There is a trend towards increased phosphorus levels in the sediment deposits in the river compared to the disturbed soils (Table 2) which would be expected since the finer fractions of the eroded material have a higher proportion of available nutrients than the original soil (Brady, 1974). The total nitrogen results for the soils and sediments do not show any obvious trends. Comparison of nutrient levels in soils from eroded and adjacent undisturbed areas may have revealed loss of nutrients resulting from erosion, but samples from undisturbed areas were not analysed during the present study.

The results for the algalsediment samples show greatly elevated levels of phosphorus, nitrogen and organic carbon, which is consistent with the presence of the algal material.

Soil leaching tests. No significant differences were observed between the sites for the release of silicon, phosphorus or nitrogen (Table 3).

The nutrient analysis showed that levels of total phosphorus and nitrogen in the algal-sediment samples were much greater than any of the soil samples. This was not reflected in the release of nitrate plus nitrite and orthophosphate in the soil leaching tests, and it appears that nutrients tied up in the algal-sediment material were not readily released in water under the conditions used in the test.

Water quality monitoring data

Turbidity and suspended solids. Daily turbidity data for one upstream site and for three downstream sites, (together with daily mean discharge at Colemans), for the period April 1976 to October 1977, were presented in EPA (1980), and the results for turbidity are summarized in Table 4. The pattern of variation was similar at all sites, but the values for the downstream sites were generally higher than for the upstream site (Table 4). A two- way Friedman analysis (Siegel, 1956), with sites as treatments

Table 1. Mineral composition of sand.

Mineral	Regulating dam site	site 2
Quartz	most common	most common
Feldspar	rare	rare
Mica	abundant	abundant
Tourmaline	present	present
Zircon	present	present
Amphibole	rare	present
Opaques (ilmenite or magnetite)	present	present
Cordierite	—	present

Table 2. Analysis of nutrients in algal/ sediment deposits and soil samples ($\mu g\ g^{-1}$).

	Total phosphorus	Total nitrogen	Organic carbon
Soil samples:			
Borrow area	1.0	270	1900
0.5 km below dam			
(i)erosion gulley	1.3	220	2000
(ii)sediment	1.9	240	2200
2 km below dam			
(i)erosion gulley	1.4	480	5000
(ii)sediment fan b.w.l.	1.7	330	3700
(iii)bank deposits b.w.l.	4.0	640	6600
Alga/sediment deposits:			
Site 1	8.0	1440	16100
Site 2	21.0	2660	27000
Regulating dam site	17.0	1960	16700

Note: b.w.l. = below water level. Analytical methods are those described in *Chemical Methods Manual*, Victorian Department of Agriculture. Phosphorus by the modified Olsen method from that manual.

Table 3. Soil leaching results. (mg atom l^{-1}).

	Soluble reactive silicon	$NO_3 + NO_2$	OrthoP
Soil samples:			
Borrow area	0.4	0.008	<0.02
2 km below dam			
(i)erosion gulley	0.3	0.008	0.04
(ii)sediment fan, b.w.l.	0.4	0.008	0.05
Algal/sediment deposit:			
Site 1	0.5	0.004	0.03

Note: b.w.l. = below water level. Orthophosphate determined by standard molybdate colorimetric method (Grigg, 1975).

and days as blocks, showed that the differences between sites were highly significant ($p < 0.001$). A treatment versus control procedure (Hollander and Wolf, 1973) indicated that levels at the upstream site were significantly less than at all downstream sites ($p < 0.001$). Monthly turbidity data indicated significant differences ($p < 0.001$) between one upstream and one downstream site when 32 sets of observations were available (dating back to February 1974) but for the comparison between three sites, for which only 17 sets of data were available, differences were not significant.

Periods of high turbidity were relatively short, rarely exceeding two days. Between these periods turbidity was usually less than 10 JTUs. From April 1976 to October 1977. Turbidity was under 10 JTUs on over 60% of the days in which records were taken (EPA, 1980).

Reliable daily suspended solids data were only available for the 116 days between March and October 1979 (EPA, 1980), and are summarised for the same four sites as the turbidity data in Table 4b. Using the same statistical analysis as for turbidity an identical pattern emerged, with concentration of suspended solids significantly ($p < 0.001$) greater at downstream sites than at the upstream site. Monthly data were again limited in usefulness by the number of sets of readings. A Wilcoxon signed rank test showed significant differences ($p < 0.02$) between an upstream and a downstream site with 25 data records. Using a Friedman two-way analysis with three sites and only 13 matching observations there was no significant difference between sites.

Nutrients. Only monthly data were available for total phosphorous, nitrate, Kjeldahl nitrogen (TKN) and silica (Table 5). Using a Wilcoxon signed rank test for comparisons of two sites (for all but Si), and a Friedmans two-way analysis for three and four sites (for total P and Si), no significant differences ($p > 0.05$) were indicated between sites for any of the nutrients. Sets of data between sites were small, with the largest being 23 readings for total phosphorous above and below the dam site.

Plots of silica concentration versus suspended solids concentration and turbidity revealed no apparent association. For the silica versus suspended solids data, the correlation coefficient was 0.027 for the 82 observations. This was not significantly different from zero ($p > 0.05$). The correlation coefficient for silica versus turbidity was 0.14, for the 98 observations, which was also not significant.

A lack of correlation between dissolved nutrients and turbidity and suspended solids was also reflected in analysis of samples taken during high turbidity associated with closure of the dam (EPA, 1980).

Discussion

Effects of sediment input on substrata and algae

Major sediment deposition below the Dartmouth Dam site was not expected because the normally substantial flow of the Mitta Mitta river remained unaltered during most of the construction period (Smith et al., 1978). At the time of that study heavy sediment deposition resulting from dam construction had not been frequently reported (an exception being Eustis and Hellen, 1954). Some reports (e.g., Briggs, 1948; Hilsenhoff, 1971) noted sediment deposits downstream of established reservoirs, but

suggested that these were due to post-dam alteration in scouring capacity, rather than to sediment deposition during construction. Further, early monitoring of suspended solids and sediment generation at Dartmouth indicated that sediment inputs from dam construction constituted at worst an approximately 33% increase over natural levels, and seemed unimportant when compared with natural year to year variation (Graham et al., 1978).

Results of this study and Blyth et al. (1984) indicate that the biological effects of construction sediment in the Mitta Mitta River have been much greater than predicted (Smith et al., 1978) or than might be expected from the results of physical and chemical monitoring. The most noticeable change in the river bed was the appearance of an algal-sediment layer covering the surfaces of rocks exposed to the current in riffle areas below the dam. The algal-sediment layer was observed as far downstream as Tallandoon, approximately 50 km below the dam, although it was greatest at the sites up to 20 km below the dam. The algal community associated with the algal- sediment layer was quite different to that existing above the dam (Blyth et al., 1984) and the growth of algal-material significantly heavier below the dam (this study).

The algal-sediment deposits showed a distinctly layered structure due to the alternation of plant matter and sediment particles, the latter presumably representing fresh influxes of sediment. Blyth and St Clair (1978) and Blyth et al. (1984) suggest that the interaction between the algae and the sediment involves a cyclic process in which sediment input stimulates the growth of some algae which can then trap more sediment, which in turn further encourages the growth of algal species. The relatively short periods of high turbidity may be important in this respect, as algal growth would be impeded by continual high turbidity. The algal species present (mainly *Oscillatoria* and *Lyngbya* spp., which are more correctly termed Cyanobacteria (Bauld, 1981)) are often motile (Blyth et al., 1984) and able to retain their position on the outside of the expanding crust.

It is unlikely that such fine sediment deposits would persist on the surface of riffle areas if they were not trapped in the algal matrix. A different situation would probably exist in pools where sedimentation would be greater than in riffle areas. Also, the growth of benthic algae might be restricted in pools because of the reduction in light intensity at the greater depths. Sedimentation in pools was not investigated in the present study because of sampling difficulties and restricted time.

A factor which may have influenced the establishment of the algal-sediment layer was the relatively low flows in the Mitta Mitta River during 1976 and 1977 (EPA, 1980). Annual flows equal to or less than those recorded for these two years would normally be expected to occur about once in five years. Perhaps more importantly, there had been no severe spates since October 1975. Round (1965) noted that there is a tendency for silt to become trapped amongst epilithic algae (attached to stones) when stream flow is reduced, and that a flora develops intermediate between the epilithic and epipelic types.

Major construction work on the Dartmouth Dam commenced in mid- 1974, and sediment input was probably higher in the early stages than in later years when turbidity and suspended sediment levels in the river were monitored daily. There were frequent severe spates during

Table 4. Maxima and means for turbidity and suspended solids at one upstream and three downstream sites.

Factor	Site	No. of samples	Max.	Mean
Turbidity (JTUs)	(a) Above dam	427	620	12.1
	(b) Below dam	396	6250	38.4
	(c) Steel Bridge	432	5500	41.6
	(d) Colemans	397	3250	42.7
Suspended solids ($mg\,l^{-1}l$)	(a) Above dam	152	133	10.1
	(b) Below dam	120	205	23.1
	(c) Steel Bridge	154	400	19.8
	(d) Colemans	120	360	23.9

Table 5. Monthly maxima and means for four nutrients at one upstream and three downstream sites.

Factor	Site	No. of samples	Max.	Mean
Total P ($mg\,l^{-1}$)	(a) Above dam	27	0.24	0.033
	(b) Below dam	32	0.12	0.032
	(c) Steel Bridge	7	0.19	0.050
	(d) Colemans	16	0.05	0.023
Nitrate ($mg\,N\,l^{-1}$)	(a) Above dam	16	0.99	0.097
	(b) Below dam	14	0.61	0.100
	(c) Steel Bridge	–	–	–
	(d) Colemans	3	0.02	0.013
TKN ($mg\,l^{-1}$)	(a) Above dam	13	0.46	0.21
	(b) Below dam	12	0.46	0.22
	(c) Steel Bridge	–	–	–
	(d) Colemans –	–	–	
Reactive silica ($mg\,SiO_2\,l^{-1}$)	(a) Above dam	33	20.9	9.3
	(b) Below dam	38	12.7	9.4
	(c) Steel Bridge	10	11.1	8.8
	(d) Colemans	22	21.1	10.0

1974 and 1975, and at the time of the National Museum survey in January 1975 (Blyth et al., 1984) there were no reported substratum changes. By the time of the next survey in November 1976, the algal-sediment layer was well established. Substratum investigations carried out in summer are however subject to some uncertainty as later surveys have indicated that the algal-sediment deposit was less noticeable at this time of year. Algal populations are subject to seasonal changes (e.g., Blum, 1956; Whitton, 1975). Species of *Stigeoclonium*, one of which is abundant in the Mitta Mitta River, are scarce in summer due to less favourable conditions for growth associated with the reduced flow (Hynes, 1970). Thus the importance of spates in preventing the establishment of the algal-sediment layer cannot be fully assessed, because of the lack of information on the time of appearance of the layer.

This study did not address the question of deep penetration of the bed by fine sediment. However, Bechta and Jackson (1979) have suggested that storm generated particles smaller than 0.2 mm fill interstitial spaces to the deepest levels, even in areas of fast current. Davey et al. (1982) showed that this did occur in artificial substrata to a depth of 60 cm, and that sediment generated from the Thomson Dam construction site in Gippsland, Victoria, was almost entirely <2 mm with most <0.25 mm. The material held in the algal/sediment mats examined in this study was virtually all <0.25 mm. It seems likely that the high stream energy during spates throughout the construction period at Dartmouth would have been sufficient to intrude such fine sediment into most available spaces throughout the bed (Bechta and Jackson, 1979).

The potential long term nature of bed sedimentation is illustrated by several studies. Platts and Megahan (1974), in a study of a river effected by siltation from intensive forestry activities, found the substratum had not returned to its original state after nine years. Eustis and Hillen (1954) used scouring flows, with only moderate success, to remove silt from below a dam in the United States. In both cases, only the effect on the bed surface was observed, not that within it, and Bechta and Jackson (1979) have suggested that fast currents only flush material from the bed to a very shallow depth. Davey et al. (1982) showed that after up to four and a half months in clean fast flowing water, artificial substrata (containing natural bed material and construction sediment) lost sediment from the first few centimetres only; deeper fine material was undisturbed.

The mineral composition of surface sediment indicated granitic soils, such as those around the construction area, as their likely source. However, despite the presence of some sharper particles, grain size and shape did not provide a precise indication of the sediment source, or its length of time in the river.

The heavy algal growth downstream of the dam focused attention on nutrient indicators. Erosion is responsible for appreciable losses of nutrients from soil, and increased productivity in streams and lakes has been attributed to nutrients lost in runoff from fertile areas where accelerated erosion is just beginning (Ryden et al., 1972).

The water quality monitoring provided no evidence of increased concentrations of total phosphorus, nitrogen (nitrate and TKN) or dissolved silica in the river water below the dam. Also, there was no significant increase in the concentrations of silica associated with high levels or turbidity. Further, the tests carried out in this study indicated little physical leaching of nutrients from soil of sediment deposits. Direct biological activity may prove to be more important than physical leaching in the release of nutrients from river sediment.

Nutrients in the interstitial water of sediments represent a potential resource for benthic algae. A number of workers have shown that levels of soluble reactive phosphorus in the interstitial water of sediments are appreciably higher than in the overlying water (Williams and Mayer, 1972; Syers et al., 1973). However, the rate of removal of nutrients from the interstitial water is dependent upon several factors, one being the circulation of water over the sediment surface. In the case of sediment deposits in fast flowing rivers such as the Mitta Mitta, a high nutrient loss from the interstitial water would be expected.

In finely eroded material a higher proportion of adsorbed nutrients is available for plant growth than in the original soil (Brady, 1974). Levels of phosphorus in soil and sediment samples showed this effect in the present study. In the algal- sediment deposit the algae are in intimate contact with the sediment, and the levels of nutrients adsorbed on particles within the deposit may be more important for algal growth than those in the water column or interstitial water. Golterman (1976) and Golterman et al. (1969) have shown that algae growing on sediments are able to effectively utilize sediment phosphorus. Several investigators have concluded that benthic diatoms can attach the aluminosilicate clay minerals and obtain silica directly from them (Hutchinson, 1957). for example, it was found that nacrite, a mineral closely related to kaolinite (present in river sediment in this study) was an adequate source of silica for diatoms in pure culture.

Monitoring aquatic systems

Results from this study and Blyth et al. (1984) highlight some of the inadequacies of conventional methods for monitoring and analysing the effects of land disturbance on aquatic systems.

The frequency of sampling can have a major effect upon the results of physical and chemical monitoring. Sediment input to streams is related to rainfall and discharge (Hynes, 1970; Beaumont, 1975; Daniel et al. 1979) and it has been shown that the maximum suspended loads are carried during a relatively small part of the flood event, normally just prior to the peak of the hydrograph (Beaumont, 1975). In this study, monthly sampling data revealed significant differences between sites, only for one site upstream and one site downstream of the construction area for which a larger data set was available. Daily data showed highly significant increases, by factors of two for suspended sediment and three for turbidity, at downstream sites. However, even daily sampling for these two parameters is likely to yield massive underestimates of total sediment loads throughout the year (Beaumont, 1975). The estimation of annual sediment loads generated by Dartmouth construction activities (Graham et al., 1978) was apparently based on daily suspended solids concentrations, and when possible, instantaneous discharge at the same time. It would have been entirely fortituous if samples had been taken at the peak of storm-induced spates. Thus, both concentration and discharge would probably have been considerably underestimated. Useful assessment of sediment loads discharged from land disturbance requires intensive monitoring of both sediment and discharge throughout storm related spates.

It is also now widely recognized that many pollutants and nutrients (including phosphorus) mainly move through aquatic systems in association with suspended solids and that monitoring of total phosphorus is not an effective measure of potential eutrophication (Ongley, 1982.) Rosich and Cullen (1982) showed that in two small catchments in the Australian Capital Territory about 90% of the annual total load of phosphorous was exported during less than 10% of the time in the year. Excluding a single thirteen-day flood event from calculations decreased the estimate of annual total phosphorus

load by a factor of almost 20 in one catchment, and over 60 in another (Rosich and Cullen, 1982). Thus, calculation of annual loads of nutrients from monthly monitoring data as carried out by Graham et al. (1978) (only turbidity and suspended solids were measured daily) is likely to yield results 'hugely in error' (Ongley, 1982). The conclusion of Graham et al. (1978) that no significant increase in critical plant nutrients had occurred as a result of construction activities can now be seen to be quite unjustified. further the apparent lack of relationship between algal stimulation shown in this study and dissolved nutrients reaffirms that routine nutrient monitoring in cases of land disturbance is not an effective way of determining biological effects.

Different methods of analysis of monitoring data can also yield very different conclusions. Graham et al. (1978) estimated the annual loads of suspended solids generated by construction activities, and concluded that in the worst year (1977) only about 30% of total suspended solids came from that source. Analysis presented herein of daily suspended solid concentrations shows that these were approximately doubled immediately downstream of the dam site over the period March to October 1977 (for which reliable data were available).

The biological significance of increased concentrations of suspended solids may depend upon the size grades involved. Davey et al. (1982) have shown that downstream of the Thomson Dam construction site, bed material under 2 mm in diameter is dominated by silt and clay (< 0.063 mm) while upstream, particles 1–2 mm in diameter dominate the fine material. Because the very finest particles can potentially penetrate the spaces within the bed, comparatively small increases may have a dramatic effect upon biota. In addition, it is the silt and clay sized particles that are most likely to carry adsorbed nutrients capable of causing the algal stimulation observed in this study (Wetzel, 1975).

Reliable and detailed criteria for protection of Australian aquatic ecosystems from the adverse effects of added sediment are not available. Both the European IFAC (1965) and the American NAS/NAE (1973) have suggested that high level protection should be provided to aquatic ecosystems if suspended solids do not exceed 25 mg l^{-1}. Hart (1974) has noted that in the absence of specific Australian information the EIFAC (1965) criterion of concentrations below 80 mg l^{-1} to support moderate to good fisheries may provide a guide. In the eight months for which reliable daly data are available at Dartmouth, suspended solids concentrations were greater than 25 mg l^{-1} at least thirteen times and greater than 80 mg l^{-1} five times downstream of the dam site. Upstream of the dam site concentrations exceeded 25 mg l^{-1} at least nine times, and 80 mg l^{-1} twice (EPA, 1980).

Clearly much work is needed to establish suitable criteria governing addition of fine sediment to Australian streams. A number of questions need to be addressed. (i) Do levels of suspended solids per se cause damage to aquatic communities (e.g., by bringing about excessive invertebrate drift as suggested by Gammon, 1970), or is it largely through blanketing the substratum and blocking spaces within the bed that adverse effects occur? (ii) Are all grades of sediment <2 mm responsible for adverse effects, or are these effects largely due to silt and clay sized particles only? (iii) Can a threshold concentration for suspended sediment be established above which the impact becomes unnacceptable? (iv) If a threshold does exist, can aquatic biota withstand, or recover from, short or occasional periods above this level, and if so what length may such periods be, and how frequently may they recur?

As indicated by this study, much routine physical and chemical water quality assessment bears little relevance to real events in aquatic systems when diffuse inputs are involved. More useful assesment requires two complementary aspects to be addressed.

First, estimates of loads of sediment, nutrients and other pollutants can only be provided by discharge related monitoring. The monitoring should be of factors relevant to the stream biota, such as nutrients associated with sediment particles rather than, or in addition to, dissolved nutrients. Further, sampling times should be based on regular proportions of discharge rather than regular time intervals (Rosich and Cullen, 1982). Secondly, monitoring of the stream biota and its habitat, including bed structure, is essential to provide a direct assessment of the final result of sediment inputs.

Such a dual approach to monitoring would provide a realistic assessment of the impacts of land disturbance. It would also help to provide the information linking physical and chemical conditions to biological response, an essential first step for the establishment of useful water quality criteria for Australian conditions.

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